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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicant: Christopher Kempson Shaw et al.	§	Confirmation No.: 9812
U.S. Application No. 10/641,350	§	Group Art Unit No.: 3672
Filing Date: 8/14/03	§	
Title: Subsea Chemical Injection Unit for Additive Injection and Monitoring System for Oilfield Operations	§	Attorney Docket No.: 194-26936-US

Attn: Mail Stop Petition
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

REQUEST FOR RECONSIDERATION OF PETITION UNDER 37 C.F.R. §1.47(a) AND PETITION FOR EXTENSION UNDER 37 C.F.R. §1.136(a)

This is a response to the Decision Refusing Status Under 37 C.F.R. §1.47(a) mailed on July 15, 2004 dismissing applicants' original petition filed on May 12, 2004.

I, Chandran D. Kumar, the undersigned attorney of record have first-hand knowledge of the following facts presented in this Request for Reconsideration of Petition Under 37 C.F.R. §1.47(a). Facts in direct response to the decision are presented below.

Applicants' previous petition, which was filed on May 12, 2004, was dismissed because the Senior Petitions Attorney concluded that Applicants did not provide "proof that the non-signing inventor cannot be reached or found, after diligent effort, or refuse to sign the oath or declaration after having been presented with the application papers (specification, claims and drawings)." Applicants were directed to, in the present renewed petition, to "establish that the entire application package, including specification, claims and drawings, was presented to the non-signing inventor Tubel and he subsequently refused to sign." As discussed below, Applicants have complied with this directive.

In support of this renewed petition, the following supporting facts are presented:

1. Mr. Tubel was sent two (2) mailings, each including the entire application package, including specification, claims, drawings, declaration and assignment. Both mailings were sent certified mail with restricted delivery to ensure that only Mr. Tubel or an

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individual authorized by Mr. Tubel could receive the application package.

3. The first mailing was dated August 9, 2004. The mailing included a cover letter signed by me with copies of the utility patent application, drawings, Declaration and Assignment and was mailed to Mr. Tubel at his business address, 4800 Research Forest Drive, The Woodlands, Texas 77381. A return receipt was returned showing delivery of documents on August 10, 2004, receipt signed by Paul Martinez. (see attached return receipt). No response has been received for this first mailing. Copies of the mailing as well as the return receipt are furnished as Exhibit A.

4. The second mailing was dated September 15, 2004. The mailing included a cover letter signed by Stephen A. Littlefield, Division Intellectual Property Counsel, Baker Petrolite with copies of the utility patent application, drawings, Declaration and Assignment and was mailed to Mr. Tubel at his business address, 4800 Research Forest Drive, The Woodlands, Texas 77381. A return receipt was returned showing delivery of documents on September 16, 2004, receipt signed by Paul Martinez. (see attached return receipt). No response has been received for this second mailing. Copies of the mailing as well as the return receipt are furnished as Exhibit B.

5. Both mailings were addressed to Mr. Tubel's business address: 4800 Research Forest Drive, The Woodlands, Texas 77381. This address is shown on the web site of Mr. Tubel's business web page, a copy of which is furnished as Exhibit C.

It is evident from the actions of Mr. Tubel to date that further reasonable efforts to obtain his joinder in the application will most likely prove unsuccessful. In order to protect the interest of Baker Hughes Incorporated, Petitioner respectfully requests that the application be accepted on behalf of Mr. Tubel by the signature of all other signing inventors.

Applicants have also attached the necessary Petition for Extension of Time, up to and including October 15, 2004. The Commissioner is authorized to charge the $110.00 one (1) month extension fee to Deposit Account 02-0429 (194-26936-US). The Commissioner is also authorized to charge any under payment or credit any overpayment associated with this

communication to Deposit Account No. 02-0429 (194-26936-US).

Respectfully submitted,

Date: October 15, 2004

Chandran D. Kumar
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CERTIFICATE OF MAILING UNDER 37 CFR 1.10

I hereby certify that the foregoing communication, and all documents referred to as enclosed or attached, are being deposited with the United States Postal Service on this 15th day of October, 2004 in an envelope as "Express Mail Post Office to Addressee" Mailing Label Number EV460271032US addressed to the M.S. Petition, Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450.

Gretchen King

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Paulo S. Tubel
Tubel Technologies Inc.
4800 Research Forest Drive
The Woodlands TX 77381

4a. Article Number
7000 1670 0006 3849 6717

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MADAN, MOSSMAN & SRIRAM, P.C.
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August 9, 2004

Certified Mail Receipt – Restricted Delivery
7000 1670 0006 3849 6717

Paulo S. Tublel
Tubel Technologies, Inc.
4800 Research Forest Drive
The Woodlands, Texas 77381

Re: U.S. Patent Application
Title: "Subsea Chemical Injection Unit for Additive Injection and Monitoring System for Oilfield Operations"
Serial No.: 10/641,350
Filing Date: August 14, 2003
Our File No.: 194-26936-US

Dear Mr. Tubel:

Enclosed are copies of the utility patent application and drawings that were filed with the USPT on August 14, 2003. Also enclosed are copies of the Declaration and Assignment that require your signature. Please sign the Declaration and Assignment and return to me at your earliest convenience in enclosed self-addressed, stamped envelope.

If you have any questions concerning this matter, please contact me.

Very truly yours,

Chandran D. Kumar
Chandran D. Kumar
Direct Dial: 713.266.1130x128
ckumar@madanlaw.com

CDK/gk
Enclosures (as noted)

EXPRESS MAIL CERTIFICATE
"EXPRESS MAIL" LABEL No EV322404795US
Date of Deposit: August 14, 2003
I hereby certify that this paper or fee and any papers referred to as being attached or enclosed are being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above, addressed to: Mail Stop: Patent Application, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Gretchen King

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APPLICATION FOR UNITED STATES PATENT

FOR

SUBSEA CHEMICAL INJECTION UNIT FOR ADDITIVE INJECTION AND MONITORING SYSTEM FOR OILFIELD OPERATIONS

Inventors: Christopher Kempson Shaw
Cindy L. Crow
Bill Aeschbacher
Sunder Ramachandran
Mitch Means
Paulo S. Tubel

Assignee: Baker Hughes Incorporated
3900 Essex Lane, Suite 1200
Houston, Texas 77027

EV322404795US

CROSS-REFERENCE TO RELATED APPLICATIONS

This application takes priority from U.S. Provisional Application serial number 60/403,445 filed August 14, 2002.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to oilfield operations and more particularly to a subsea chemical injection and fluid processing systems and methods.

2. Background of the Art

Conventional offshore production facilities often have a floating or fixed platforms stationed at the water's surface and subsea equipment such as a well head positioned over the subsea wells at the mud line of a seabed. The production wells drilled in a subsea formation typically produce fluids (which can include one or more of oil, gas and water) to the subsea well head. This fluid (wellbore fluid) is carried to the platform via a riser or to a subsea fluid separation unit for processing. Often, a variety of chemicals (also referred to herein as "additives") are introduced into these production wells and processing units to control, among other things, corrosion, scale, paraffin, emulsion, hydrates, hydrogen sulfide, asphaltenes, inorganics and formation of other harmful chemicals. In offshore oilfields, a single offshore platform (e.g., vessel, semi-submersible or fixed system) can be used to supply these additives to several producing wells.

The equipment used to inject additives includes at the surface a chemical supply unit, a chemical injection unit, and a capillary or tubing (also referred to herein as "conductor line") that runs from the offshore platform through or along the riser and into the subsea wellbore. Preferably, the additive injection systems supply precise amounts of additives. It is also desirable for these systems to periodically or continuously monitor the actual amount of the additives being dispensed, determine the impact of the dispersed additives, and vary the amount of dispersed additives as needed to maintain certain desired parameters of interest within their respective desired ranges or at their desired values.

In conventional arrangements, however, the chemical injection unit is positioned at the water surface (e.g., on the offshore platform or a vessel), which can be several hundred to thousands of feet) from the subsea wellhead. Moreover, the tubing may direct the additives to produced fluids in the wellbores located hundreds or thousands of feet below the seabed floor. The distance separating the chemical injection unit and the locus of injection activity can reduce the effectiveness of the additive injection process. For example, it is known that the wellbore is a dynamic environment wherein pressure, temperature, and composition of formation fluids can continuously fluctuate or change. The distance between the surface-located chemical injection unit and the subsea environment introduces friction losses and a lag between the sensing of a given condition and the execution of measures for addressing that condition. Thus, for instance, a conventionally located chemical injection unit may inject chemicals to remedy a condition that has since changed.

The present invention addresses the above-noted problems and provides an enhanced additive injection system suitable for subsea applications.

SUMMARY OF THE INVENTION

This invention provides a system and method for deployment of chemicals or additives in subsea oilwell operations. The chemicals used prevent or reduce build up of harmful elements, such as paraffin or scale and prevent or reduce corrosion of hardware in the wellbore and at the seabed, including pipes and also promote separation and/or processing of formation fluids produced by subsea wellbores. In one aspect, the system includes one or more subsea mounted tanks for storing chemicals, one or more subsea pumping systems for injecting or pumping chemicals into one or more wellbores and/or subsea processing units(s), a system for supplying chemicals to the subsea tanks, which may be via an umbilical interfacing the subsea tanks to a surface chemical supply unit or a remotely-controlled unit or vehicle that can either replace the empty subsea tanks with chemical filled tanks or fill the subsea tanks with the chemicals. The subsea tanks may also be replaced by any other conventional methods. The surface and subsea tanks may include multiple compartments or separate tanks to hold different chemicals which can be deployed into wellbores at different or same time. The subsea chemical injection unit can be sealed in a water-tight enclosure. The subsea chemical storage and injection system decreases the viscosity problems related to pumping chemicals from the surface through umbilical capillary tubings to a subsea installation location that may in some cases be up to 20 miles from the surface pumping station.

The system includes sensors associated with the subsea tank, the subsea pipes carrying the produced fluids, the wellbore, the umbilical and the surface facilities. The surface to subsea interface may use fiber optic cables to monitor the condition of the umbilical and the lines and provide chemical, physical and environmental data, such as chemical composition, pressure, temperature, viscosity etc. Fiber optic sensors along with conventional sensors may also be utilized in the system wellbore. Other suitable sensors to determine the chemical and physical characteristics of the chemical being injected into the wellbore and the fluid extracted from the wellbore may also be used. The sensors may be distributed throughout the system to provide data relating to the properties of the chemicals, the wellbore produced fluid, processed fluid at subsea processing unit and surface unit and the health and operation of the various subsea and surface

equipment.

The surface supply units may include tanks carried by a platform or vessel or buoys associated with the subsea wells. Electric power at the surface may be generated from solar power or from conventional power generators. Hydraulic power units are provided for surface and subsea chemical injection units. Controllers at the surface alone or at subsea locations or in combination control the operation of the subsea injection system in response to one or parameters of interests relating to the system and/or in response to programmed instructions. A two-way telemetry system preferably provides data communication between the subsea system and the surface equipment. Commands from the surface unit are received by the subsea injection unit and the equipment and controllers located in the wellbores. The signals and data are transmitted between and/or among equipment, subsea chemical injection, fluid processing units, and surface equipment. A remote unit, such as at a land facility, may also be provided. The remote location then is made capable of controlling the operation of the chemical injection units of the system of the present invention.

In one embodiment, the present invention provides a subsea additive injection system for treating formation fluids. In one mode, the system injects, monitors and controls the supply of additives into fluids recovered through subsea production wellbores. The system can include a surface facility having a supply unit for supplying additives to a chemical injection unit located at a subsea location.

The chemical injection unit includes a pump and a controller. The pump supplies, under pressure, a selected additive from a chemical supply unit into the subsea wellbore via a suitable supply line. In one embodiment, one or more additives are pumped from an umbilical disposed on the outside of a riser extending to a surface facility. In another embodiment, the additives are supplied from one or more subsea tanks. The controller at a seabed location determines additive flow rate and controls the operation of the pump according to stored parameters in the controller. The subsea controller adjusts the flow rate of the additive to the wellbore to achieve the desired level of chemical additives.

The system of the present invention may be configured for multiple production wells. In one embodiment, such a system includes a separate pump, a fluid line and a subsea controller for each subsea well. Alternatively, a suitable

common subsea controller may be provided to communicate with and to control multiple wellsite pumps via addressable signaling. A separate flow meter for each pump provides signals representative of the flow rate for its associated pump to the onsite common controller. The seabed controller at least periodically polls each flow meter and performs the above-described functions. If a common additive is used for a number of wells, a single additive source may be used. A single or common pump may also be used with a separate control valve in each supply line that is controlled by the controller to adjust their respective flow rates. The additive injection of the present invention may also utilize a mixer wherein different additives are mixed or combined at the wellsite and the combined mixture is injected by a common pump and metered by a common meter. The seabed controller controls the amounts of the various additives into the mixer.

The additive injection system may further include a plurality of sensors downhole which provide signals representative of one or more parameters of interest. Parameter of interest can include the status, operation and condition of equipment (e.g., valves) and the characteristics of the produced fluid, such as the presence or formation of sulfites, hydrogen sulfide, paraffin, emulsion, scale, asphaltenes, hydrates, fluid flow rates from various perforated zones, flow rates through downhole valves, downhole pressures and any other desired parameter. The system may also include sensors or testers that provide information about the characteristics of the produced fluid. The measurements relating to these various parameters are provided to the wellsite controller which interacts with one or more models or programs provided to the controller or determines the amount of the various additives to be injected into the wellbore and/or into a subsea fluid treatment unit and then causes the system to inject the correct amounts of such additives. In one aspect, the system continuously or periodically updates the models based on the various operating conditions and then controls the additive injection in response to the updated models. This provides a closed-loop system wherein static or dynamic models may be utilized to monitor and control the additive injection process. The additives injected using the present invention are injected in very small amounts. Preferably, the flow rate for an additive injected using the present invention is at a rate such that the additive is present at a concentration of from about 1 parts per million (ppm) to

about 10,000 ppm in the fluid being treated.

The surface facility supports subsea chemical injection and monitoring activities. In one embodiment, the surface facility is an offshore rig that provides power and has a chemical supply that provides additives to one or more injection units. This embodiment includes an offshore platform having a chemical supply unit, a production fluid processing unit, and a power supply. Disposed outside of the riser are a power transmission line and umbilical bundle, which transfer electrical power and additives, respectively, from the surface facility to the subsea chemical injection unit. The umbilical bundle can include metal conductors, fiber optic wires, and hydraulic lines.

In another embodiment, the surface facility includes a relatively stationary buoy and a mobile service vessel. The buoy provides access to an umbilical adapted to convey chemicals to the subsea chemical injection unit. In one embodiment, the buoy includes a hull, a port assembly, a power unit, a transceiver, and one or more processors. The umbilical includes an outer protective riser, tubing adapted to convey additives, power lines, and data transmission lines having metal conductors and/or fiber optic wires. The power lines transmit energy from the power unit to the chemical injection unit and/or other subsea equipment. In certain embodiments, the transceiver and processors cooperate to monitor subsea operating conditions via the data transmission lines. Sensors may be positioned in the chemical supply unit, the production fluid processing unit, and the riser. The signals provided by these sensors can be used to optimize operation of the chemical injection unit. The service vessel includes a surface chemical supply unit and a docking station or other suitable equipment for engaging the buoy and/or the port. During deployment, the service vessel visits one or more buoys, and, pumps one or more chemicals to the chemical injection unit via the port and umbilical.

Examples of the more important features of the invention have been summarized rather broadly in order that the detailed description thereof that follows may be better understood and in order that the contributions they represent to the art may be appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject of the claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

For a detailed understanding of the present invention, reference should be made to the following detailed description of the one mode embodiments, taken in conjunction with the accompanying drawings, in which like elements have been given like numerals, wherein:

Figure 1 is a schematic illustration of an offshore production facility having an additive injection and monitoring system made according to one embodiment of the present invention;

Figure 2 is a schematic illustration of a additive injection and monitoring system according to one embodiment of the present invention;

Figure 3 shows a functional diagram depicting one embodiment of the system for controlling and monitoring the injection of additives into multiple wellbores, utilizing a central controller on an addressable control bus;

Figure 4 is a schematic illustration of a wellsite additive injection system which responds to in-situ measurements of downhole and surface parameters of interests according to one embodiment of the present invention;

Figure 5A is a schematic illustration of a surface facility having a platform according to one embodiment of the present invention; and

Figure 5B is a schematic illustration of a surface facility having a service vessel and buoy made according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring initially to **Figure 1**, there is schematically shown a chemical injection and monitoring system **100** (hereafter "system **100**") made in accordance with the present invention. The system **100** may be deployed in conjunction with a surface facility **110** located at a water's surface **112** that services one or more subsea production wells **60** residing in a seabed **116**. Conventionally, each well **60** includes a well head **114** and related equipment positioned over a wellbore **118** formed in a subterranean formation **120**. The well bores **118** can have one or more production zones **122** for draining hydrocarbons from the formation **120** ("produced fluids" or "production fluid"). The production fluid is conveyed to a surface collection facility (e.g., surface facility **110** or separate structure) or a subsea collection and/or processing facility **126** via a line

127. The fluid may be conveyed to the surface facility **110**-via a line **128** in an untreated state or, preferably, after being processed, at least partially, by the production fluid-processing unit **126.**

The system **100** includes a surface chemical supply unit **130** at the surface facility **110**, a single or multiple umbilicals **140** disposed inside or outside of the riser **124**, one or more sensors **S**, a subsea chemical injection unit **150** located at a remote subsea location (*e.g.*, at or near the seabed **116**), and a controller **152**. The sensors **S** are shown collectively and at representative locations; *i.e.,* water surface, wellhead, and wellbore. In some embodiments, the system **100** can include a power supply **153** and a fluid-processing unit **154** positioned on the surface facility **110**. The umbilical **140** can include hydraulic lines **140h** for supplying pressurized hydraulic fluid, one or more tubes for supplying additives **140c**, and power/data transmission lines **140b** and **140d** such as metal conductors or fiber optic wires for exchanging data and control signals. The chemical injection unit can be sealed in a water-tight enclosure.

During production operations, in one embodiment the surface chemical supply unit **130** supplies (or pumps) one or more additives to the chemical injection unit **150**. The surface chemical supply unit **130** may include multiple tanks for storing different chemicals and one or more pumps to pump chemicals to the subsea tank **131**. This supply of additives may be continuous. Multiple subsea tanks may be used to store a pre-determined amount of each chemical. These tanks **131** then are replenished as needed by the surface supply unit **130**. The chemical injection unit **150** selectively injects these additives into the production fluid at one or more pre-determined locations. In a one mode of operation, the controller **152** receives signals from the sensors **S** regarding a parameter of interest which may relate to a characteristic of the produced fluid. The parameters of interest can relate, for example, to environmental conditions or the health of equipment. Representative parameters include but are not limited to temperature, pressure, flow rate, a measure of one or more of hydrate, asphaltene, corrosion, chemical composition, wax or emulsion, amount of water, and viscosity. Based on the data provided by the sensors **S**, the controller **152** determines the appropriate amount of one or more additives needed to maintain a desired or pre-determined flow rate or other operational criteria and alters the operation of the chemical injection unit **150** accordingly. A surface controller

152S may be used to provide signals to the subsea controller **152** to control the delivery of additives to the wellbore **118** and/or the processing unit **126**.

Referring now to **Figure 2**, there shown a schematic diagram of a subsea chemical injection system **150** according to one embodiment of the present invention. The system **150** is adapted to inject additives **13a** into the wellbore **118** and/or into a subsea surface treatment or processing unit **126.** The system **150** is further adapted to monitor pre-determined conditions (discussed later) and alter the injection process accordingly. The wellbore **118** is shown as a production well using typical completion equipment. The wellbore **118** has a production zone **122** that includes multiple perforations **54** through the formation **120.** Formation fluid **56** enters a production tubing **59** in the well **118** via perforations **54** and passages **62**. A screen **58** in the annulus **51** between the production tubing **59** and the formation **120** prevents the flow of solids into the production tubing **59** and also reduces the velocity of the formation fluid entering into the production tubing **59** to acceptable levels. An upper packer **64a** above the perforations **54** and a lower packer **64b** in the annulus **51** respectively isolate the production zone **122** from the annulus **51a** above and annulus **51b** below the production zone **122.** A flow control valve **66** in the production tubing **59** can be used to control the fluid flow to the seabed surface **116**. A flow control valve **67** may be placed in the production tubing **62** below the perforations **54** to control fluid flow from any production zone below the production zone **122.**

A smaller diameter tubing **68**, may be used to carry the fluid from the production zones to the subsea wellhead **114**. The production well **118** usually includes a casing **40** near the seabed surface **116.** The wellhead **114** includes equipment such as a blowout preventor stack **44** and passages **14** for supplying fluids into the wellbore **118.** Valves (not shown) are provided to control fluid flow to the seabed surface **116**. Wellhead equipment and production well equipment, such as shown in the production well **118**, are well known and thus are not described in greater detail.

Referring still to **Figure 2**, in one aspect of the present invention, the desired additive **13a** is injected into the wellbore **118** via an injection line **14** by a suitable pump, such as a positive displacement pump **18** ("additive pump"). In one aspect, the additive **13a** flows through the line **14** and discharges into the production tubing **60** near the production zone **122** via inlets or passages **15**.

The same or different injection lines may be used to supply additives to different production zones. In **Figure 2**, line **14** is shown extending to a production zone below the zone **122.** Separate injection lines allow injection of different additives at different well depths. The additives **13a** may be supplied from a tank **131** that is periodically filled via the supply line **140**. Alternatively, the additives **13a** may be supplied directly from the surface chemical supply **130** via supply line **140c**. The tank **131** may include multiple compartments and may be replaceable tanks which is periodically replaced. A level sensor S_L can provide to the controller **152** or **152S** (Fig. 1) indication of the additive remaining in the tank **131**. When the additive level falls below a predetermined level, the tank is replenished or replaced. Alternatively a remotely operated vehicle **700** ("ROV") may be used to replenish the tank via feed line **140**. The ROV **700** attaches to the supply line and replenishes the tank **131**. Other conventional methods may be used to replace tank **131**. Replaceable tanks are preferably quick disconnect types (e.g., mechanical, hydraulic, etc.). Of course, certain embodiments can include a combination of supply arrangements.

In one embodiment, a suitable high-precision, low-flow, flow meter **20** (such as gear-type meter or a nutating meter) measures the flow rate through line **14** and provides signals representative of the flow rate. The pump **18** is operated by a suitable device **22** such as a motor. The stroke of the pump **18** defines fluid volume output per stroke. The pump stroke and/or the pump speed are controlled, e.g., by a 4 - 20 milliamperes control signal to control the output of the pump **18**. The control of air supply controls a pneumatic pump. Any suitable pump and monitoring system may be used to inject additives into the wellbore **118**.

In one embodiment of the present invention, a seabed controller **80** controls the operation of the pump **18** by utilizing programs stored in a memory **91** associated with the subsea controller **80**. The subsea controller **80** preferably includes a microprocessor **90**, resident memory **91** which may include read only memories (ROM) for storing programs, tables and models, and random access memories (RAM) for storing data. The microprocessor **90** utilizes signals from the flow meter **20** received via line **21** and programs stored in the memory **91** to determine the flow rate of the additive. The wellsite controller **80** can be programmed to alter the pump speed, pump stroke or air supply to deliver the

desired amount of the additive **13a**. The pump speed or stroke, as the case may be, is increased if the measured amount of the additive injected is less than the desired amount and decreased if the injected amount is greater than the desired amount.

The seabed controller **80** preferably includes protocols so that the flow meter **20**, pump control device **22**, and data links **85** made by different manufacturers can be utilized in the system **150**. In the oil industry, the analog output for pump control is typically configured for 0-5 VDC or 4-20 milliampere (mA) signal. In one mode, the subsea controller **80** can be programmed to operate for such output. This allows for the system **150** to be used with existing pump controllers. A power unit **89** provides power to the controller **80**, converter **83** and other electrical circuit elements. The power unit **89** can include an AC power unit, an onsite generator, and/or an electrical battery that is periodically charged from energy supplied from a surface location. Alternatively, power may be supplied from the surface via a power line disposed along the riser **124** (discussed in detail below).

Still referring to **Figure 2**, the produced fluid **69** received at the seabed surface **116** may be processed by a treatment unit or processing unit **126.** The seabed processing unit **126** may be of the type that processes the fluid **69** to remove solids and certain other materials such as hydrogen sulfide, or that processes the fluid **69** to produce semi-refined to refined products. In such systems, it is desired to periodically or continuously inject certain additives. Thus, the system **150** shown in **Figure 1** can be used for injecting and monitoring additives **13b** into the processing unit **126.** These additives may be the same or different from the additives injected into the wellbore **118**. These additives **13b** are suitable to process the produced wellbore fluid before transporting it to the surface. In configuration of **Fig. 2**, the same chemical injection unit may be utilized to pump chemicals in multiple wellbores, subsea pipelines and/or subsea processing units.

In addition to the flow rate signals **21** from the flow meter **20**, the seabed controller **80** may be configured to receive signals representative of other parameters, such as the rpm of the pump **18**, or the motor **22** or the modulating frequency of a solenoid valve. In one mode of operation, the wellsite controller **80** periodically polls the meter **20** and automatically adjusts the pump controller

22 via an analog input **22a** or alternatively via a digital signal of a solenoid controlled system (pneumatic pumps). The controller **80** also can be programmed to determine whether the pump output, as measured by the meter **20**, corresponds to the level of signal **22a**. This information can be used to determine the pump efficiency. It can also be an indication of a leak or another abnormality relating to the pump **18**. Other sensors **94**, such as vibration sensors, temperature sensors may be used to determine the physical condition of the pump **18**. Sensors **S** that determine properties of the wellbore fluid can provide information of the treatment effectiveness of the additive being injected. Representative sensors include, but are not limited to, a temperature sensor, a viscosity sensor, a fluid flow rate sensor, a pressure sensor, a sensor to determine chemical composition of the production fluid, a water cut sensor, an optical sensor, and a sensor to determine a measure of at least one of asphaltene, wax, hydrate, emulsion, foam or corrosion. The information provided by these sensors can then be used to adjust the additive flow rate as more fully described below in reference to **Figure 3** and **4**.

It should be understood that a relatively small amount of additives are injected into the production fluid during operation. Accordingly, rather considerations such as precision in dispensing additives can be more relevant than mere volumetric capacity. Preferably, the flow rate for an additive injected using the present invention is at a rate such that the additive is present at a concentration of from about 1 parts per million (ppm) to about 10,000 ppm in the fluid being treated. More preferably, the flow rate for an additive injected using the present invention is at a rate such that the additive is present at a concentration of from about 1 ppm to about 500 ppm in the fluid being treated. Most preferably the flow rate for an additive injected using the present invention is at a rate such that the additive is present at a concentration of from about 10 ppm to about 400 ppm in the fluid being treated.

As noted above, it is common to drill several wellbores from the same location. For example, it is common to drill 10-20 wellbores from a single offshore platform. After the wells are completed and producing, a separate subsea pump and meter are installed to inject additives into each such wellbore.

Figure 3 shows a functional diagram depicting a system **200** for controlling and monitoring the injection of additives into multiple wellbores **202a-**

202m according to one embodiment of the present invention. In the system configuration of **Figure3**, a separate pump supplies an additive via supply lines **140** from a surface chemical supply **130 (Fig. 1)** to each of the wellbores **202a-202m**. For example, pump **204a** supplies an additive and the meter **208a** measures the flow rate of the additive into the wellbore **202a** and provides corresponding signals to a central wellsite controller **240**. The wellsite controller **240** in response to the flow meter signals and the programmed instructions controls the operation of pump control device or pump controller **210a** via a bus **241** using addressable signaling for the pump controller **210a**. Alternatively, the wellsite controller **240** may be connected to the pump controllers via a separate line. The wellsite controller **240** also receives signal from sensor **S1a** associated with pump **204a** via line **212a** and from sensor **S2a** associated with the pump controller **210a** via line **212a**. Such sensors may include rpm sensor, vibration sensor or any other sensor that provides information about a parameter of interest of such devices. Additives to the wells **202b-202m** are respectively supplied by pumps **204b-204m** from sources **206b-206m**. Pump controllers **210b-210m** respectively control pumps **204b-204m** while flow meters **208b-208m** respectively measure flow rates to the wells **202b-202m**. Lines **212b-212m** and lines **214b-214m** respectively communicate signals from sensor $\mathbf{S_{1b}}$-$\mathbf{S_{1m}}$ and $\mathbf{S_{2b}}$-$\mathbf{S_{2m}}$ to the central controller **240**. The controller **240** utilizes memory **246** for storing data in memory **244** for storing programs in the manner described above in reference to system **100** of **Figure 1**. The individual controllers communicate with the sensors, pump controllers and remote controller via suitable corresponding connections.

The central wellsite controller **240** controls each pump independently. The controller **240** can be programmed to determine or evaluate the condition of each of the pumps **204a-204m** from the sensor signals $\mathbf{S_{1a}}$-$\mathbf{S_{1m}}$ and $\mathbf{S_{2a}}$-$\mathbf{S_{2m}}$. For example the controller **240** can be programmed to determine the vibration and rpm for each pump. This can provide information about the effectiveness of each such pump.

Figure 4 is a schematic illustration of a closed-loop additive injection system **300** which responds to measurements of downhole and surface parameters of interest according to one embodiment of the present invention. Certain elements of the system **300** are common with the system **150** of **Figure**

2. For convenience, such common elements have been designated in **Figure 4** with the same numerals as specified in **Figure 2**.

The well **118** in **Figure 4** further includes a number of downhole sensors S_{3a}-S_{3m} for providing measurements relating to various downhole parameters. The sensors may be is located at wellhead over the at least one wellbore, in the wellbore, and/or in a supply line between the wellhead and the subsea chemical injection unit. Sensor S_{3a} provide a measure of chemical and physical characteristics of the downhole fluid, which may include a measure of the paraffins, hydrates, sulfides, scale, asphaltenes, emulsion, etc. Other sensors and devices S_{3m} may be provided to determine the fluid flow rate through perforations **54** or through one or more devices in the well **118.** These sensors may be distributed along the wellbore and may include fiber optic and other sensors. The signals from the sensors may be partially or fully processed downhole or may be sent uphole via signal/date lines **302** to a wellsite controller **340**. In the configuration of **Figure 3**, a common central control unit **340** is preferably utilized. The control unit is a microprocessor-based unit and includes necessary memory devices for storing programs and data.

The system **300** may include a mixer **310** for mixing or combining at the wellsite a plurality of **additive #1 - additive #m** stored in sources **313a-312m** respectively. The sources 313a-**312m** are supplied with additives via supply line **140**. In some situations, it is desirable to transport certain additives in their component forms and mix them at the wellsite for safety and environmental reasons. For example, the final or combined additives may be toxic, although while the component parts may be non-toxic. Additives may be shipped in concentrated form and combined with diluents at the wellsite prior to injection into the well **118.** In one embodiment of the present invention, additives to be combined, such as additives **additive #1-additive #m** are metered into the mixer by associated pumps **314a-314m**. Meters **316a-316m** measure the amounts of the additives from sources **312a-312m** and provide corresponding signals to the control unit **340**, which controls the pumps **314a-314m** to accurately dispense the desired amounts into the mixer **310**. A pump **318** pumps the combined additives from the mixer **310** into the wellbore **118**, while the meter **320** measures the amount of the dispensed additive and provides the measurement signals to the controller **340**. A second additive required to be injected into the well **118** may be

stored in the source tank **131**, from which source a pump **324** pumps the required amount of the additive into the well. A meter **326** provides the actual amount of the additive dispensed from the source tank **131**to the controller **340**, which in turn controls the pump **324** to dispense the correct amount.

The wellbore fluid reaching the surface may be tested on site with a testing unit **330**. The testing unit **330** provides measurements respecting the characteristics of the retrieved fluid to the central controller **340**. The central controller utilizing information from the downhole sensors S_{3a}-S_{3m}, the tester unit data and data from any other surface sensor (as described in reference to **Figure 2**) computes the effectiveness of the additives being supplied to the well **118** and determine therefrom the correct amounts of the additives and then alters the amounts, if necessary, of the additives to the required levels. The controller **340** may also receive commands from the surface controller **152s** and/or a remote controller **152s** to control and/or monitor the wells **202a-202m**

Thus, the system of the present invention at least periodically monitors the actual amounts of the various additives being dispensed, determines the effectiveness of the dispensed additives, at least with respect to maintaining certain parameters of interest within their respective predetermined ranges, determines the health of the downhole equipment, such as the flow rates and corrosion, determines the amounts of the additives that would improve the effectiveness of the system and then causes the system to dispense additives according to newly computed amounts. The models **344** may be dynamic models in that they are updated based on the sensor inputs.

The system of the present invention can automatically take broad range of actions to assure proper flow of hydrocarbons through pipelines, which not only can minimize the formation of hydrates but also the formation of other harmful elements such as asphaltenes. Since the system **300** is closed loop in nature and responds to the in-situ measurements of the characteristics of the treated fluid and the equipment in the fluid flow path, it can administer the optimum amounts of the various additives to the wellbore or pipeline to maintain the various parameters of interest within their respective limits or ranges.

Referring now to Figure **5A,** there is shown one embodiment of a surface facility and a remote control station for supporting and controlling the subsea chemical injection and monitoring activities of a subsea chemical injection

system, such as system **150** of **Figure 1**. The Figure **5A** surface facility **500** can provide power and additives as needed to one or more subsea chemical injection units **150** **(Fig. 1)**. Also, the surface facility **500** includes equipment for processing, testing and storing produced fluids. A one mode surface facility **500** includes an offshore platform or rig or a vessel **510** having a chemical supply unit **520**, a production fluid processing unit **530**, a power supply **540**, a controller **532** and may include a remote controller **533** via a satellite or other long distance means. The chemical supply unit **520** may include separate tanks for each type of chemical desired to be supplied therefrom to the chemical injection unit **150** **(Fig. 1)** via a supply line or umbilical bundle **522** that is disposed inside or outside of a riser **550**. Each chemical/additive can either have a dedicated supply line (*i.e.*, multiple lines) or share one or more supply lines. Likewise, the umbilical bundle **522** can include power and/or data transmission lines **544** for transmitting power from the power supply **540** to the subsea components of the system **100** and transmitting data and control signals between the surface controller **532** and the subsea controller **152** **(Fig. 1)**. Suitable lines **544** include fiber optic wires and metal conductors adapted to convey data, electrical signals and power. The processing unit **530** receives produced fluid from the well head **114** **(Fig. 1)** via the riser **550**. Sensors $\mathbf{S_4}$ may be positioned in the chemical supply unit **520**, the production fluid processing unit **530**, and the riser **550** (sensors $\mathbf{S_{4a\text{-}c}}$, respectively). Sensors **S4c** may be distributed along the riser and/or umbilical to provide signals representative of fluid flow, physical and chemical characteristics of the additives and production fluid and environmental conditions. As explained earlier, measurement provided by these sensors can be used to optimize operation of the chemical injection unit **150** **(Fig. 1)**. It will be appreciated that a single surface facility as shown in **Figure 5A** may be used to service multiple subsea oilfields.

Referring now to **Figure 5B,** there is shown another embodiment of a surface facility. The **Figure 5B** surface facility **600** supplies additives on-demand or on a pre-determined basis to the chemical injection unit **150** **(Fig. 1)** without using a dedicated chemical supply unit. A one mode surface facility **600** includes a buoy **610** and a service vessel **630**.

The buoy **610** provides a relatively stationary access to an umbilical **611** and a riser **612** adapted to convey power, data, control signals, and chemicals to

the chemical injection unit **150** (**Fig. 1**). The buoy **610** includes a hull **614**, a port assembly **616**, a power unit **618**, a transceiver **620**, and one or more processors **624**. The hull **614** is of a conventional design and can be fixed, floating, semi-submersed, or full submersed. In certain embodiments, the hull **614** can include known components such as ballast tanks that provide for selective buoyancy. The port **616** is suitably disposed on the hull **614** and is in fluid communication with the conduit **612**. The conduit **612** includes an outer protective riser **612a** and the umbilical **611**, which can include single or multiple tubing **612b** adapted to convey chemicals and additives, power lines **612c**, and data transmission lines **612d**. The power lines **612d** transmit stored or generated power of the power unit **618** to the chemical injection unit (**Fig. 1**) and/or other subsea equipment. The power lines **612d** can also include hydraulic lines for conveying hydraulic fluid to subsea equipment. Power may be generated by a conventional generator **622** and/or stored in batteries **621** which can be charged via a solar power generation system **619**. The transceiver **620** and processors **624** cooperate to monitor subsea operating conditions via the data transmission lines **612d**. The data transmission lines can use metal conductors or fiber optic wires. In certain embodiments, the transceiver **620** and processors **624** can determine whether any subsea equipment is malfunctioning or whether the chemical injection unit **130** (**Fig. 1**) will exhaust its supply of one or more additives. Upon making such a determination, the transceiver **620** can be used to transmit this determination to a control facility (not shown). Sensors $\mathbf{S_5}$ may be positioned in the production fluid processing unit **640** (sensor $\mathbf{S_{5a}}$), the riser **612** (sensor $\mathbf{S_{5b}}$), or other suitable location. As explained earlier, measurement provided by these sensors can be used to optimize operation of the chemical injection unit **130** (**Fig. 1**). The subsea chemical injection unit can be sealed in a water-tight enclosure.

The service vessel **630** includes a surface chemical supply unit **632** and a suitable equipment (not shown) for engaging the buoy **610** and/or the port **616**. The service vessel **630** may be self-powered (*e.g.*, a ship or a towed structure). During deployment, the service vessel **630** visits one or more buoys **610** on a determined schedule or on an as-needed basis. Upon making up a connection to the port **616**, one or more chemicals is pumped down to the chemical storage tank **130** (**Fig. 1**) via the tubing **612b**. After the pumping operation is complete, the buoy **610** is released and the service vessel **630** is free to visit other buoys

610. It should be appreciated that the buoy **630** according to the present invention are less expensive than conventional offshore platforms.

Produced fluid from the well head **114 (Fig. 1)** is conveyed via a line **632** to a fluid processing unit **640**. The processed produced fluids are then transferred to a surface or subsea collection facility via line **642**.

Referring to **Figure 1, 5A** and **5B,** the system may further include devices that heat production fluid in subsea lines, such as line **127**. The power for heating devices **(189)** can be tapped from power supplied by the surface unit to the subsea chemical injection unit **150** or to any other subsea device, such as wellhead valves. The sensors **S** monitor the condition of the production fluid. The system of **Figures 1-5** controls and monitors the injection of chemicals into subsea wellbores **118.** A subsea chemical injection alone can control and monitor the injection of chemicals into wellbores **118** and underwater processing facility **126**. The system can also monitor the fluid carry lines **127**. The unit **150** can control and monitor the chemical injection in response to various sensor measurements or according to programmed instructions. The chemical sensor in the system provides information from various places along the wellbore **118**, pipe**127**, fluid processing unit **126**, and riser **124** or **150**. The other sensors provide information about the physical or environmental conditions. The subsea controller **152**, the surface controller **152s** and the remote controller **152s** cooperate with each other and in response to one or more sensor measurements in parameters of interest control and/or monitor the operation of the entire system shown in **Figs. 1-5**.

While the foregoing disclosure is directed to the one mode embodiments of the invention, various modifications will be apparent to those skilled in the art. It is intended that all variations within the scope and spirit of the appended claims be embraced by the foregoing disclosure.

WHAT IS CLAIMED IS:

1. A system for injecting one or more additives into production fluid produced by at least one subsea well, the system comprising:
    a) a surface chemical supply unit for supplying at least one chemical to a selected subsea location;
    b) at least one chemical supply line for carrying the at least one chemical from the surface to the selected subsea location; and
    c) a subsea chemical injection unit at the selected subsea location receiving the at least one chemical from the surface chemical supply unit and selectively injecting the at least one chemical into the production fluid.

2. The system of claim 1 further comprising a controller that controls the amount of the at least one chemical injected in response to at least one parameter of interest.

3. The system of claim 1 wherein the parameter of interest is one of (i) temperature, (ii) pressure, (iii) flow rate, (iv) a measure of one of hydrate, asphaltene, corrosion, chemical composition, wax or emulsion, (v) amount of water, and (vi) viscosity.

4. The system of claim 3 further comprising at least one sensor for providing information about the at least one parameter interest, said at least one sensor being selected from a group consisting of a temperature sensor, a viscosity sensor, a fluid flow rate sensor, a pressure sensor, a sensor to determine chemical composition of the production fluid, a water cut sensor, an optical sensor, and a sensor to determine a measure of at least one of asphaltene, wax, hydrate, emulsion, foam and corrosion.

5. The system of claim 1 wherein the subsea chemical injection unit includes a storage unit for storing the at least one chemicals supplied by the surface chemical supply unit.

6. The system of claim 5 wherein the at least one chemical supply line includes a plurality of lines for carrying a plurality of chemical to the subsea chemical injection unit.

7. The system of claim 6 wherein the surface chemical supply unit supplies a plurality of chemicals to the subsea chemical injection unit via the plurality of lines.

8. The system of claim 1 wherein the surface chemical supply unit is located on an offshore rig.

9. The system of claim 1 wherein the surface chemical supply unit includes a buoy at the sea surface and wherein the at least one chemical supply line carries chemicals from the buoy to the selected subsea location.

10. The system of claim 9 wherein the buoy includes a chemical storage unit that is periodically filled.

11. The system of claim 10 wherein the at least one supply line includes a plurality of supply lines, one for each chemical, between the buoy and the selected subsea location.

12. The system of claim 1 wherein the subsea chemical injection unit further comprises a manifold for mixing at least two chemicals prior to injecting the at least two chemicals into the production fluid.

13. The system of claim 1 wherein the subsea chemical injection unit comprises one of a control valve and control pump for controlling the amount of the at least one chemical injected into the at least one subsea well.

14. The system of claim 1 further comprising a subsea power unit for supplying power to the chemical injection unit.

15. The system of claim 14 wherein the subsea power unit includes an electrical battery that is periodically charged from energy supplied from a surface location.

16. The system of claim 1 further comprising a riser for transporting production fluid to the surface and wherein the at least one chemical supply line is located at one of (i) inside the riser, and (ii) outside the riser.

17. The system of claim 1 further comprising a plurality of sensors distributed along a production fluid path.

18. The system of claim 4 wherein the at least one sensor is located at one of (i) wellhead over the at least one wellbore, (ii) in the wellbore, and (iii) in a supply line between the wellhead and the subsea chemical injection unit.

19. The system of claim 1 wherein the at least one subsea well includes a plurality of wells and the subsea chemical injection unit separately supplies the at least one chemical to each said subsea well.

20. The system of claim 1 further comprising a subsea fluid-processing unit receiving the production fluid via a line.

21. The system of claim 1 wherein the subsea chemical injection unit injects the at least one chemical into one of (i) the at least one subsea well, (ii) a subsea fluid processing unit, and (iii) in a subsea pipeline carrying the production fluid.

22. The system of claim 1 further comprising a heating device deployed subsea to heat the production fluid.

23. The system of claim 1 further comprising a surface controller for controlling one of: (i) at least in part the operation of the subsea chemical injection unit and (ii) the supply of the at least one chemical.

24. The system of claim 23 further comprising a remote controller providing command signals to the surface controller to control the injection of the at least one chemical.

25. The system of claim 1 further comprising a plurality of distributed sensors associated with said at least one chemical supply line for providing signals relating to a characteristic of the at least one chemical carried by the at least one chemical supply line.

26. The system of claim 25 wherein the surface chemical supply unit controls the supply of the at least one chemical in response to the signals relating to the characteristic of the at least one chemical in the supply line.

27. The system of claim 22 further comprising a power unit at the surface that provides power to the heating device.

28. The system of claim 20 wherein the processing unit refines at least partially the production fluid.

29. the system of claim 28 further comprising a fluid line carrying processed fluid from the processing unit to the surface.

30. A flow assurance method for fluid produced ("production fluid") by at least one subsea well comprising:

a) providing a surface chemical supply unit at a location remote from the at least one subsea well for supplying at least one chemical to a selected subsea location;

b) providing at least one chemical supply line for carrying the at least one chemical from the surface to the selected subsea location;

c) measuring a parameter of interest relating to a characteristic of the production fluid; and

d) providing a subsea chemical injection unit at the selected subsea location for receiving the at least one chemical from the surface chemical supply unit via the at least one chemical supply line and for selectively injecting the at least one chemical into the production fluid, at least in part in response to the parameter of interest.

31. The method of claim 30 wherein measuring the parameter of interest includes measuring one of temperature, viscosity, fluid flow rate, pressure and chemical composition of the produced fluid, a measure of asphaltene, wax, hydrate, emulsion, foam, corrosion, or water, and an optical property of the production fluid.

32. The method of claim 30 further comprising locating an end of the at least one chemical supply line at a buoy at the water surface.

33. The method of claim 32 further comprising moving the surface chemical supply unit to the buoy to supply the at least one chemical to the subsea chemical injection unit via the at least one supply line.

34. The method of claim 32 wherein the at least one supply line includes a plurality of supply lines and the surface chemical supply unit pumps a separate chemical through each of the plurality of supply lines.

35. The method of claim 30 wherein the subsea chemical injection unit includes: (i) a pump for injecting the at least one chemical into the production fluid; (ii) a flow control valve; and (iii) a controller that controls the flow control valve to control the amount of chemical injected into the at least one subsea well.

36. A system for injecting a chemical into formation fluid produced by at least one subsea well, comprising: (i) a chemical supply system for supplying a desired chemical; and (ii) an underwater chemical injection unit injecting chemical into the formation fluid produced by the at least one subsea well.

37. The system of claim 36 further comprising at least one sensor providing a measurement of a parameter of interest.

38. The system of claim 37 wherein the underwater chemical injection unit includes a controller that controls at least in part the injection of the chemical in response to the parameter of interest.

39. The system of claim 37 wherein the parameter of interest is one of interest in one of: (i) a physical property of the formation stored; (ii) a chemical property of the formation fluid; or (iii) a parameter relating to a device associated with the at least one subsea well.

40. The system of claim 36 wherein the chemical injection unit injects the chemical at one of: (i) at a location within the at least one wellbore, and (ii) at a location at the seabed.

41. The system of claim 37 wherein the chemical supply system includes: (i) an underwater storage tank for storing the chemical therein; and (ii) a chemical supply unit at the sea surface that supplies the chemical to the underwater storage tank.

42. The system of claim 36 wherein the chemical supply system includes an underwater chemical storage tank that is adapted to be one of: (i)

refillable by a remotely operated device and (ii) replaceable via a quick disconnect.

ABSTRACT

A system monitors and controls the injection of additives into formation fluids recovered through a subsea well. The system includes a chemical injection unit and a controller positioned at a remote subsea location. The injection unit uses a pump to supply one or more selected additives from a subsea and/or remote supply unit. The controller operates the pump to control the additive flow rate based on signals provided by sensors measuring a parameter of interest. A one mode system includes a surface facility for supporting the subsea chemical injection and monitoring activities. In one embodiment, the surface facility is an offshore rig that provides power and has a chemical supply that provides additives to one or more injection units. In another embodiment, the surface facility includes a relatively stationary buoy and a mobile service vessel. When needed, the service vessel transfers additives to the chemical injection units via the buoy.

Inventor: Christopher Kempson Shaw et al
Serial No.: New Application
Atty Docket: 014-26936-USP1
Express Mail Label No.: EL516647621US

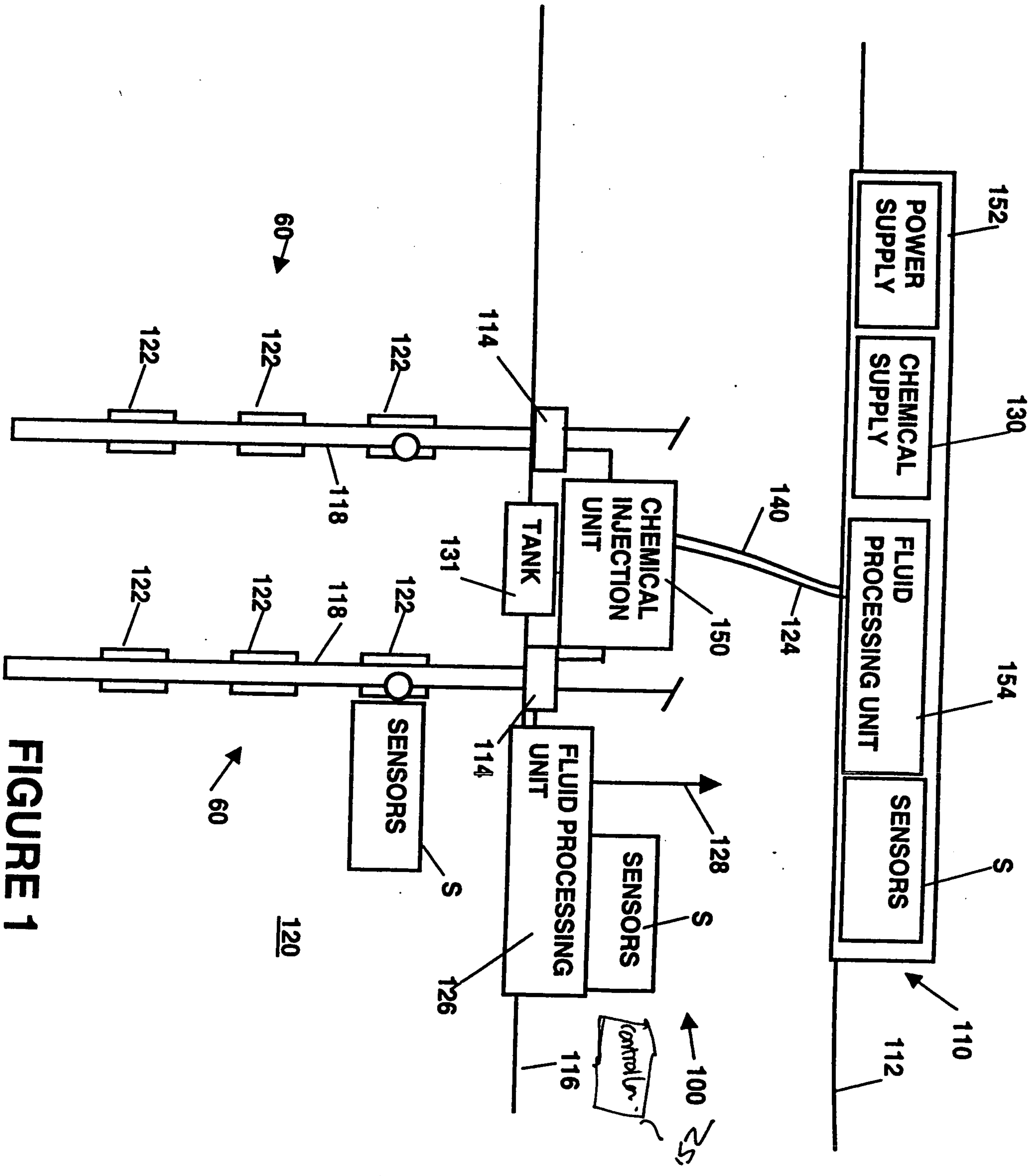
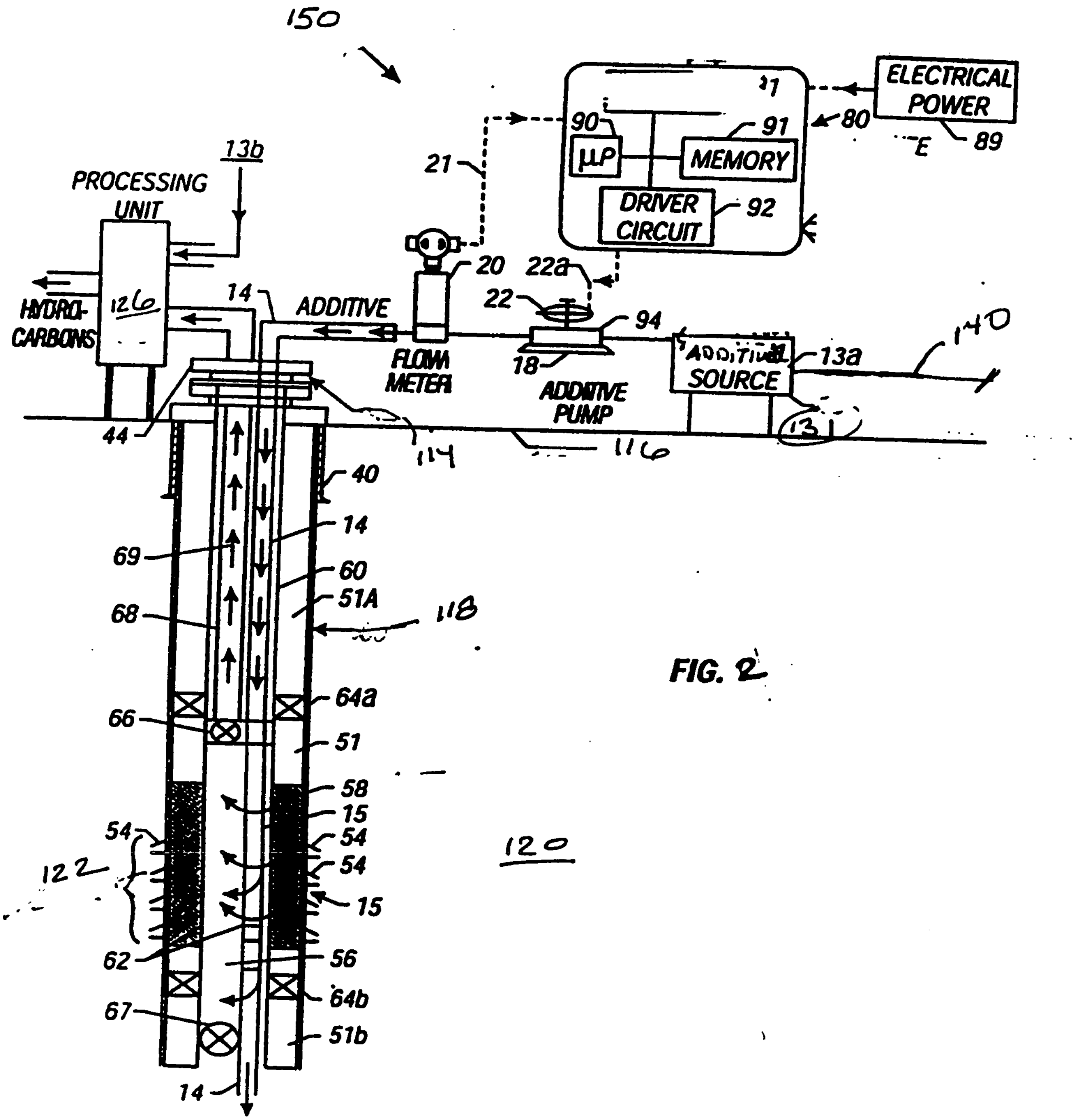


FIGURE 1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80
90
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µP
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DRIVER CIRCUIT
92
21
13b
PROCESSING UNIT
126
HYDRO-CARBONS
14
ADDITIVE
20
22a
22
94
FLOW METER
18
ADDITIVE PUMP
ADDITIVE SOURCE
13a
140
131
44
114
116
40
14
69
60
51A
68
118
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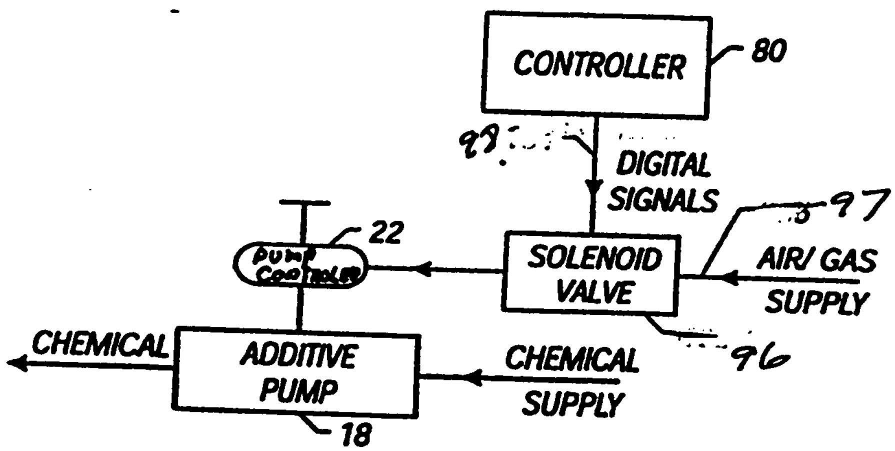
51b
14
120

FIG. 2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98
DIGITAL
SIGNALS
97
22
PUMP
CONTROLLER
SOLENOID
VALVE
AIR/ GAS
SUPPLY
96
CHEMICAL
ADDITIVE
PUMP
CHEMICAL
SUPPLY
18

FIG. 3

Inven' : Christopher Kempson Shaw et al
Serial No.: New Application
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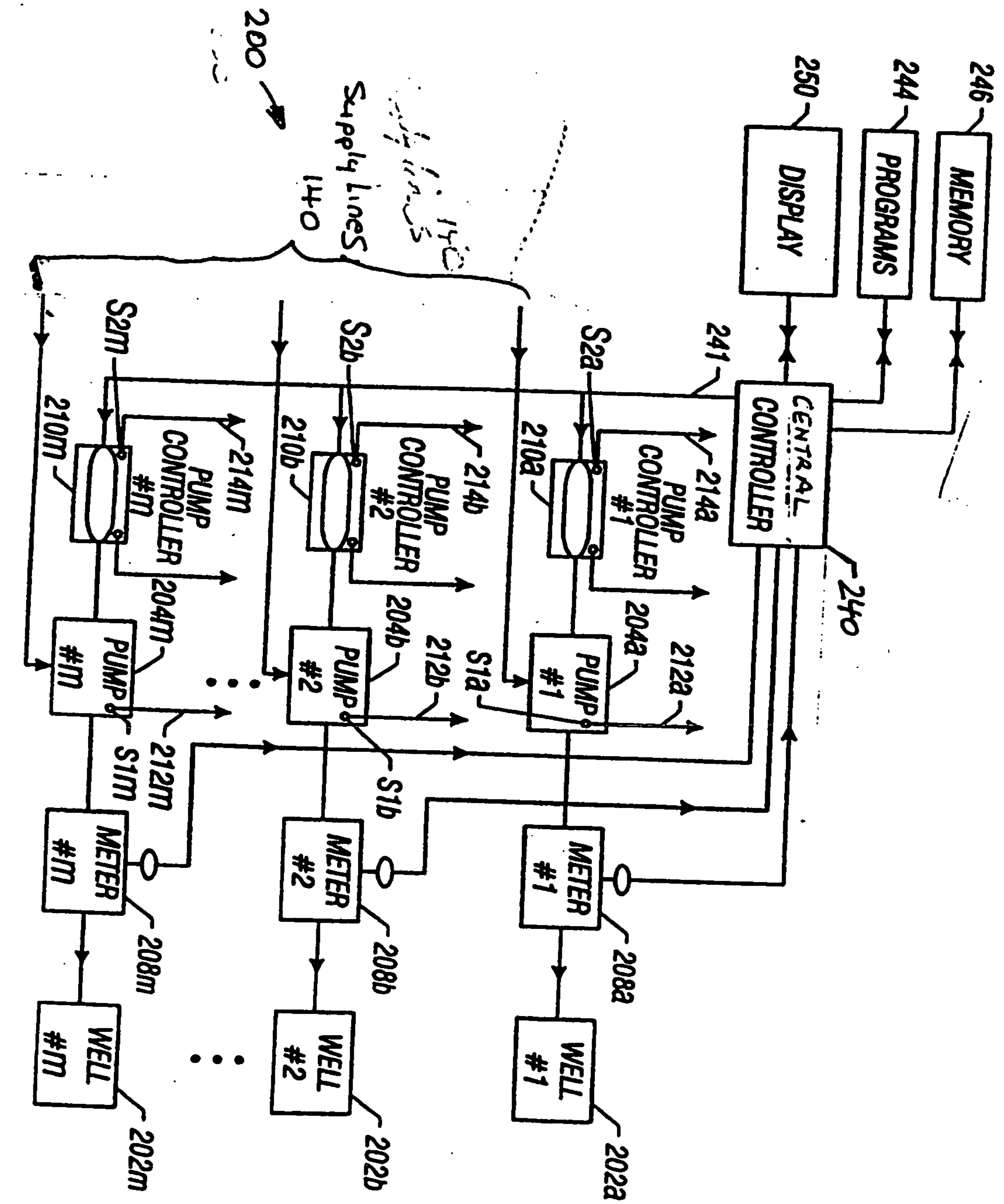

FIGURE 4

Inventor: Christopher Kempson Shaw et al
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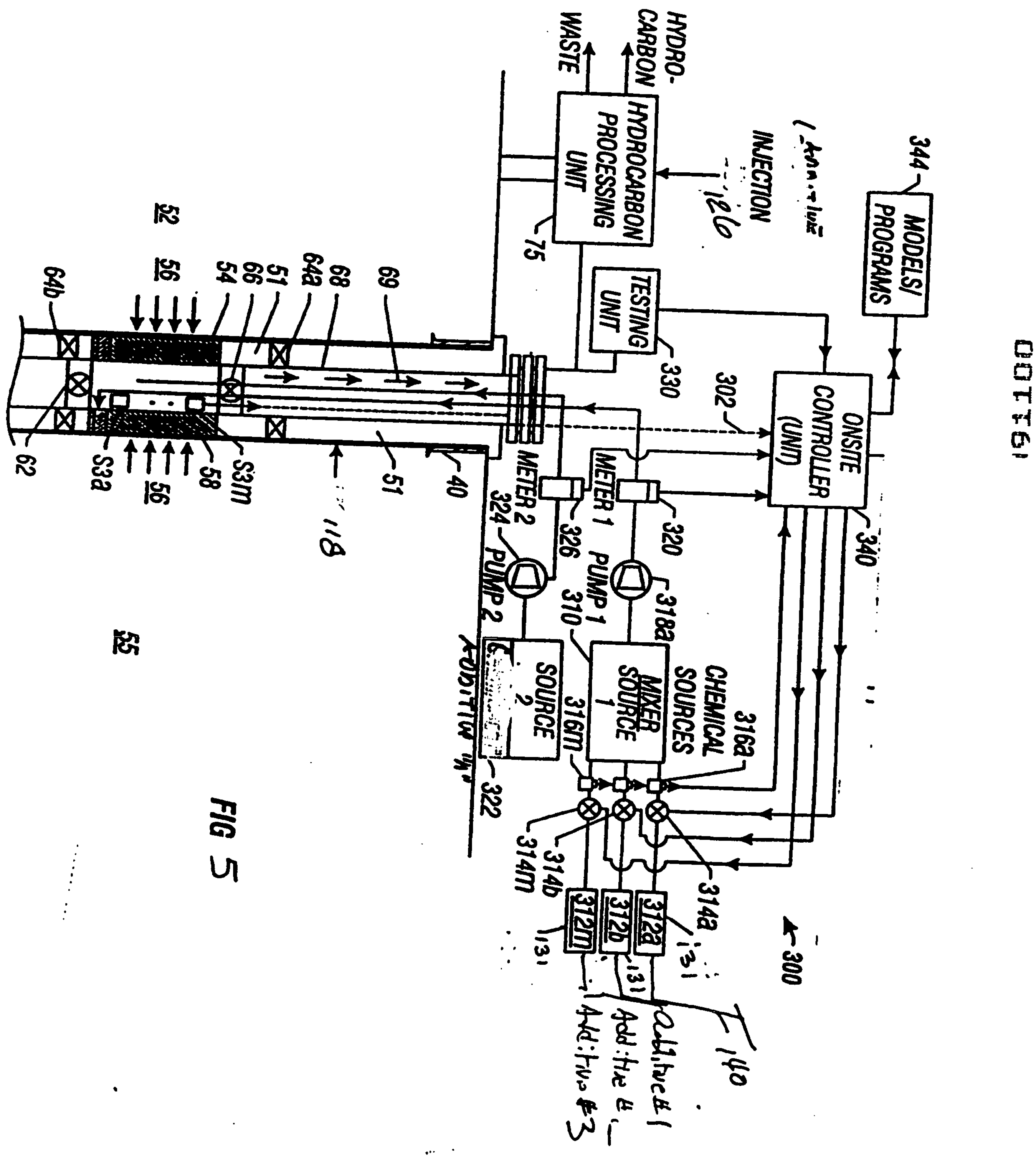

FIG 5

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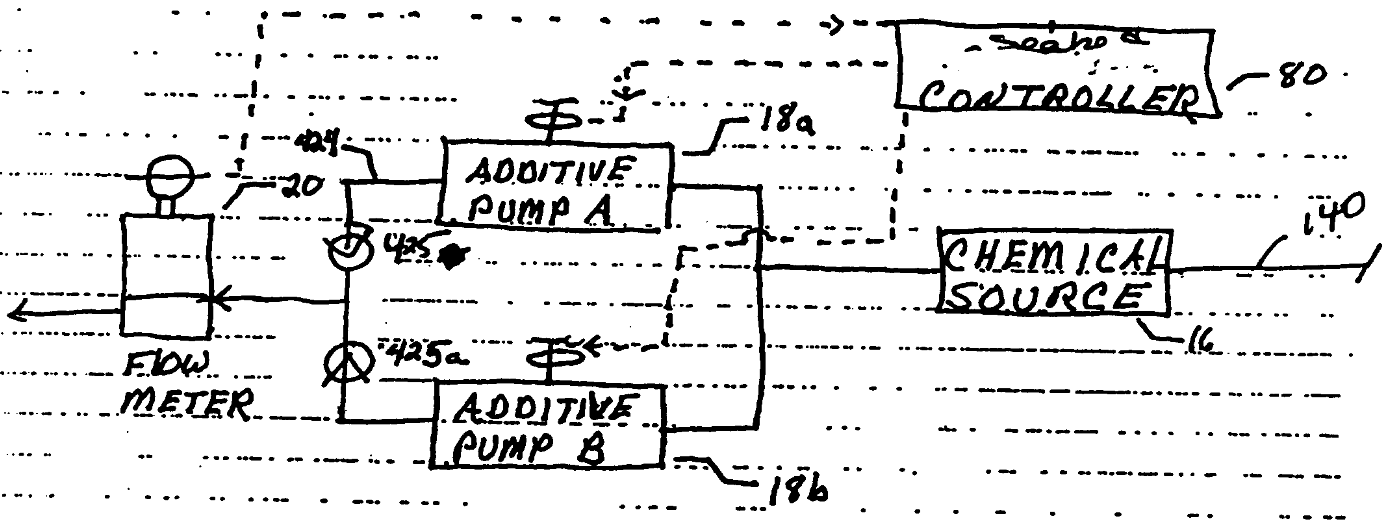

FIGURE 6

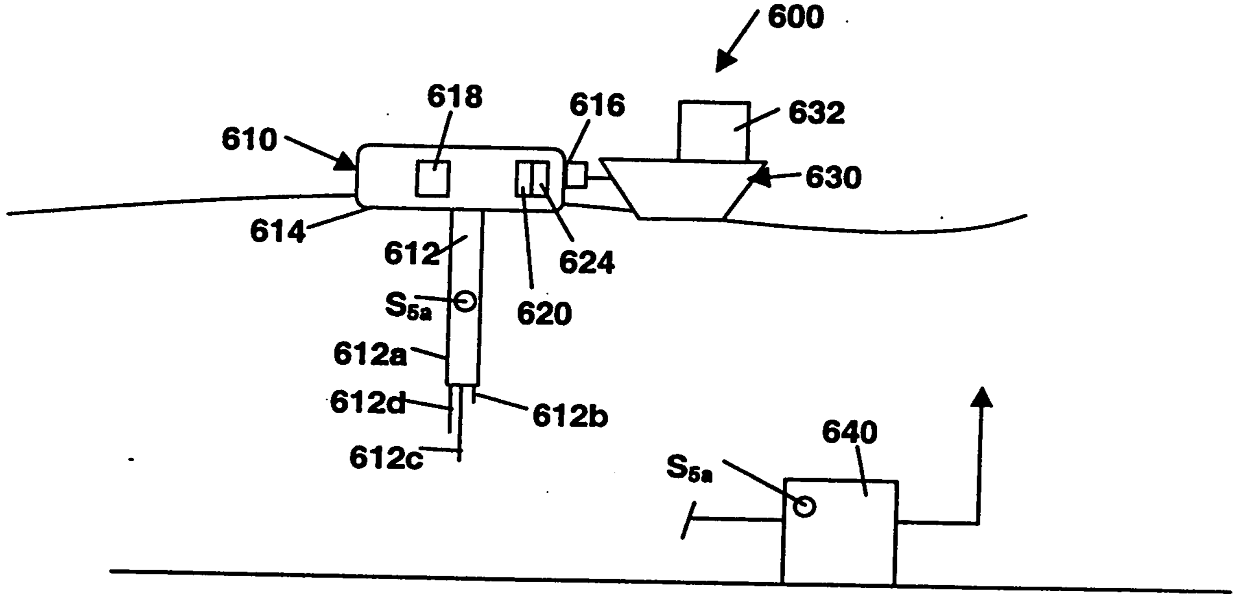

FIGURE 7B

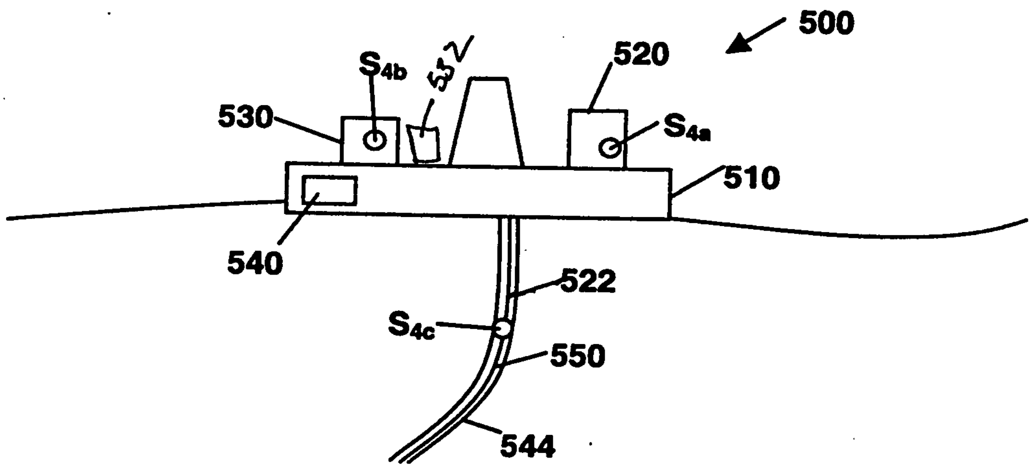

FIGURE 7A

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As the below named inventors, we hereby declare that:

Our residence, post office address and citizenship are as stated below under our names.

We believe that we are the original, first and joint inventors of the subject matter which is claimed and for which a patent is sought on the invention entitled **"Subsea Chemical Injection Unit for Additive Injection and Monitoring System for Oilfield Operations,"** the specification of which was filed on **August 14, 2003**, receiving the Serial No. **10/641,350.**

We hereby state that we have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

We acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Sec. 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

We hereby claim foreign priority benefits under Title 35, United States Code, Sec. 119(a)-(d) or (f), or 365(b), of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below any foreign application for patent or inventor's certificate, or any PCT international application having a filing date before that of the application on which priority is claimed.

PRIOR FOREIGN APPLICATION(S)

NUMBER	COUNTRY	(DAY/MONTH/YEAR FILED)	PRIORITY CLAIMED	
			YES	NO

We hereby claim benefit under Title 35, USC, Sec. 120 of any United States application, or under Title 35, USC Sec. 119(e) of any provisional application, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in any prior United States application in the manner provided by the first paragraph of Title 35, USC, Sec. 112. I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, which became available between the filing date of the prior application and the national or PCT international filing date of this application:

SERIAL NO.	FILING DATE	STATUS
60/403,445	August 14, 2002	

We hereby appoint, Stephen A. Littlefield (Reg. No. 27,923), Matt W. Carson (Reg. No. 33,662), J. Albert Riddle (Reg. No. 33,445), Darryl M. Springs (Reg. No. 24,799), Brian S. Welborn (Reg. No. 39,065), Timothy Donoughue (Reg. No. 46,668), Paul S. Madan (Reg. No. 33,011), Kaushik P. Sriram (Reg. No. 43,150), David L. Mossman (Reg. No. 29,570), G.

Michael Roebuck (Reg. No. 35,662), Todd A. Bynum (Reg. No. 39,488),), Gene L. Tyler (Reg. No. 35,395), William E. Schmidt (Reg. No. 47,064), Chandran D. Kumar (48,679), David A. Walker (Reg. No. 52,334), and Shawn Hunter (Reg. No. 36,168) as attorneys with full power of substitution and revocation to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

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Direct all telephone calls to Chandran D. Kumar at (713) 266-1130x128.

We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Sec. 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Date

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Date

Paulo S. Tubel

ASSIGNMENT

IN CONSIDERATION OF ONE (1) DOLLAR AND OTHER GOOD AND VALUABLE CONSIDERATION, the receipt, sufficiency and adequacy of which are hereby acknowledged, the undersigned, do/does hereby:

SELL, ASSIGN AND TRANSFER to **BAKER HUGHES INCORPORATED**, having a place of business at **3900 ESSEX LANE, SUITE 1200, HOUSTON, TEXAS 77027**, the entire right, title and interest for the United States and all foreign countries in and to any and all inventions and improvements which are disclosed in the application for United States Letters Patent, which has been executed by the undersigned and is entitled **"SUBSEA CHEMICAL INJECTION UNIT FOR ADDITIVE INJECTION AND MONITORING SYSTEM FOR OILFIELD OPERATIONS,"** further identified as U.S. Application Serial No. **10/641,350**, filed **August 14, 2003**, such application and all divisional, continuing, substitute, renewal, reissue and all other applications for patent which have been or shall be filed in the United States and all foreign countries on any of such inventions or improvements; all original and reissued patents which have been or shall be issued in the United States and all foreign countries on such inventions or improvements; and specifically including the right to file foreign applications under the provisions of any convention or treaty and claim priority based on such application in the United States;

AUTHORIZE AND HEREBY REQUEST the issuing authorities to issue any and all United States and foreign patents granted on such inventions or improvements to **BAKER HUGHES INCORPORATED**;

WARRANT AND COVENANT that no assignment, grant, mortgage, license or other agreement affecting the rights and property herein conveyed has been or will be made to others by the undersigned, and that the full right to convey the same as herein expressed is possessed by the undersigned;

COVENANT, when requested and at the expense of the Assignee, to carry out in good faith the intent and purposes of this assignment, the undersigned will execute all divisional, continuing, substitute, renewal, reissue, and all other patent applications on any and all such improvements; execute all rightful oaths, declarations, assignments, powers of attorney and other papers; communicate to the Assignee all facts known to the undersigned relating to such improvements and the history thereof; and generally do everything possible which the Assignee shall consider desirable for vesting title to such improvements in the Assignee, and for securing, maintaining and enforcing proper patent protection for such improvements;

TO BE BINDING on the heirs, assigns, representatives and successors of the undersigned and extend to the successors, assigns and nominees of the Assignee.

IN WITNESS WHEREOF, the undersigned have hereunto subscribed their names on the date set opposite their signatures.

(Signature) ______________________________ Date ______________________
Name: Christopher Kempson Shaw

§
§

BEFORE ME, the undersigned authority, on this _____ day of ________, 2003 personally appeared the person, Christopher Kempson Shaw, whose name is subscribed to the foregoing instrument and acknowledged to me that he executed the same of his own free will for the purposes and consideration therein expressed.

____
Notary Public

(Signature) ______________________________ Date ______________________
Name: Cindy L. Crow

§
§

BEFORE ME, the undersigned authority, on this _____ day of ________, 2003 personally appeared the person, Cindy L. Crow, whose name is subscribed to the foregoing instrument and acknowledged to me that he executed the same of his own free will for the purposes and consideration therein expressed.

____
Notary Public

(Signature) ______________________________ Date ______________________
Name: William Edward Aeschbacher, Jr.

§
§

BEFORE ME, the undersigned authority, on this _____ day of ________, 2003 personally appeared the person, William Edward Aeschbacher, Jr., whose name is subscribed to the foregoing instrument and acknowledged to me that he executed the same of his own free will for the purposes and consideration therein expressed.

____
Notary Public

(Signature) ______________________________ Date ________________________
Name: Sunder Ramachandran

§
§

BEFORE ME, the undersigned authority, on this ____ day of ________, 2003 personally appeared the person, Sunder Ramachandran, whose name is subscribed to the foregoing instrument and acknowledged to me that he executed the same of his own free will for the purposes and consideration therein expressed.

____
Notary Public

(Signature) ______________________________ Date ________________________
Name: Mitch C. Means
§
§

BEFORE ME, the undersigned authority, on this ____ day of ________, 2003 personally appeared the person, Mitch C. Means, whose name is subscribed to the foregoing instrument and acknowledged to me that he executed the same of his own free will for the purposes and consideration therein expressed.

____
Notary Public

(Signature) ______________________________ Date ________________________
Name: Paulo S. Tubel

§
§

BEFORE ME, the undersigned authority, on this ____ day of ________, 2004 personally appeared the person, Paulo S. Tubel, whose name is subscribed to the foregoing instrument and acknowledged to me that he executed the same of his own free will for the purposes and consideration therein expressed.

____
Notary Public

SENDER: COMPLETE THIS SECTION

- Complete items 1, 2, and 3. Also complete item 4 if Restricted Delivery is desired.
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PAUL S. TUBEL
TUBEL Technologies Inc.
4800 Research Forest Dr.
The Woodlands, TX 77381

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X Paul Martinez

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BAKER HUGHES

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VIA REGISTERED MAIL; RETURN RECEIPT REQUESTED

September 15, 2004

Mr. Paul S. Tubel
Tubel Technologies, Inc.
4800 Research Forest Drive
The Woodlands, Texas 77381

Re: Patent Application for "Subsea Chemical Injection Unit for Additive Injection and Monitoring System for Oilfield Operations"; Our ref.: 194-26936-US

Dear Paul:

Enclosed for your review are the specification, claims and drawings for the above-referenced patent application. Also, enclosed for your execution are the Declaration/Power of Attorney and Assignment (the Documents for Execution) for this patent application.

As you are aware, we have been attempting to complete the filing for the above-referenced patent application for some time now. Our April 30, 2004 Letter furnished you with the Documents for Execution and our August 9, 2004 Letter furnished you the complete application as well as the Documents for Execution. Both of these letters have gone unanswered. Moreover, our telephone calls to your offices regarding this matter have not been returned.

Given our past cordial relationship, we are at a loss as to your refusal to execute these documents. In any event, at your earliest convenience, please review and sign/date the enclosed Declaration/Power of Attorney and Assignment and mail them to me with the enclosed prepaid Express Mail envelope. If you have any questions, please feel free to contact me or my assistant, Penny Pfeffer (phone 281-276-5770; e-mail penny.pfeffer@bakerhughes.com).

Sincerely,

Steve

Stephen A. Littlefield

/SAL
Encls.

EXPRESS MAIL CERTIFICATE
"EXPRESS MAIL" LABEL No EV322404795US
Date of Deposit: August 14, 2003
I hereby certify that this paper or fee and any papers referred to as being attached or enclosed are being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above, addressed to: Mail Stop: Patent Application, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

Gretchen King

Gretchen King

APPLICATION FOR UNITED STATES PATENT

FOR

SUBSEA CHEMICAL INJECTION UNIT FOR ADDITIVE INJECTION AND MONITORING SYSTEM FOR OILFIELD OPERATIONS

Inventors: Christopher Kempson Shaw
Cindy L. Crow
Bill Aeschbacher
Sunder Ramachandran
Mitch Means
Paulo S. Tubel

Assignee: Baker Hughes Incorporated
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EV322404795US

CROSS-REFERENCE TO RELATED APPLICATIONS

This application takes priority from U.S. Provisional Application serial number 60/403,445 filed August 14, 2002.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to oilfield operations and more particularly to a subsea chemical injection and fluid processing systems and methods.

2. Background of the Art

Conventional offshore production facilities often have a floating or fixed platforms stationed at the water's surface and subsea equipment such as a well head positioned over the subsea wells at the mud line of a seabed. The production wells drilled in a subsea formation typically produce fluids (which can include one or more of oil, gas and water) to the subsea well head. This fluid (wellbore fluid) is carried to the platform via a riser or to a subsea fluid separation unit for processing. Often, a variety of chemicals (also referred to herein as "additives") are introduced into these production wells and processing units to control, among other things, corrosion, scale, paraffin, emulsion, hydrates, hydrogen sulfide, asphaltenes, inorganics and formation of other harmful chemicals. In offshore oilfields, a single offshore platform (e.g., vessel, semi-submersible or fixed system) can be used to supply these additives to several producing wells.

The equipment used to inject additives includes at the surface a chemical supply unit, a chemical injection unit, and a capillary or tubing (also referred to herein as "conductor line") that runs from the offshore platform through or along the riser and into the subsea wellbore. Preferably, the additive injection systems supply precise amounts of additives. It is also desirable for these systems to periodically or continuously monitor the actual amount of the additives being dispensed, determine the impact of the dispersed additives, and vary the amount of dispersed additives as needed to maintain certain desired parameters of interest within their respective desired ranges or at their desired values.

In conventional arrangements, however, the chemical injection unit is positioned at the water surface (e.g., on the offshore platform or a vessel), which can be several hundred to thousands of feet) from the subsea wellhead. Moreover, the tubing may direct the additives to produced fluids in the wellbores located hundreds or thousands of feet below the seabed floor. The distance separating the chemical injection unit and the locus of injection activity can reduce the effectiveness of the additive injection process. For example, it is known that the wellbore is a dynamic environment wherein pressure, temperature, and composition of formation fluids can continuously fluctuate or change. The distance between the surface-located chemical injection unit and the subsea environment introduces friction losses and a lag between the sensing of a given condition and the execution of measures for addressing that condition. Thus, for instance, a conventionally located chemical injection unit may inject chemicals to remedy a condition that has since changed.

The present invention addresses the above-noted problems and provides an enhanced additive injection system suitable for subsea applications.

SUMMARY OF THE INVENTION

This invention provides a system and method for deployment of chemicals or additives in subsea oilwell operations. The chemicals used prevent or reduce build up of harmful elements, such as paraffin or scale and prevent or reduce corrosion of hardware in the wellbore and at the seabed, including pipes and also promote separation and/or processing of formation fluids produced by subsea wellbores. In one aspect, the system includes one or more subsea mounted tanks for storing chemicals, one or more subsea pumping systems for injecting or pumping chemicals into one or more wellbores and/or subsea processing units(s), a system for supplying chemicals to the subsea tanks, which may be via an umbilical interfacing the subsea tanks to a surface chemical supply unit or a remotely-controlled unit or vehicle that can either replace the empty subsea tanks with chemical filled tanks or fill the subsea tanks with the chemicals. The subsea tanks may also be replaced by any other conventional methods. The surface and subsea tanks may include multiple compartments or separate tanks to hold different chemicals which can be deployed into wellbores at different or same time. The subsea chemical injection unit can be sealed in a water-tight enclosure. The subsea chemical storage and injection system decreases the viscosity problems related to pumping chemicals from the surface through umbilical capillary tubings to a subsea installation location that may in some cases be up to 20 miles from the surface pumping station.

The system includes sensors associated with the subsea tank, the subsea pipes carrying the produced fluids, the wellbore, the umbilical and the surface facilities. The surface to subsea interface may use fiber optic cables to monitor the condition of the umbilical and the lines and provide chemical, physical and environmental data, such as chemical composition, pressure, temperature, viscosity etc. Fiber optic sensors along with conventional sensors may also be utilized in the system wellbore. Other suitable sensors to determine the chemical and physical characteristics of the chemical being injected into the wellbore and the fluid extracted from the wellbore may also be used. The sensors may be distributed throughout the system to provide data relating to the properties of the chemicals, the wellbore produced fluid, processed fluid at subsea processing unit and surface unit and the health and operation of the various subsea and surface

equipment.

The surface supply units may include tanks carried by a platform or vessel or buoys associated with the subsea wells. Electric power at the surface may be generated from solar power or from conventional power generators. Hydraulic power units are provided for surface and subsea chemical injection units. Controllers at the surface alone or at subsea locations or in combination control the operation of the subsea injection system in response to one or parameters of interests relating to the system and/or in response to programmed instructions. A two-way telemetry system preferably provides data communication between the subsea system and the surface equipment. Commands from the surface unit are received by the subsea injection unit and the equipment and controllers located in the wellbores. The signals and data are transmitted between and/or among equipment, subsea chemical injection, fluid processing units, and surface equipment. A remote unit, such as at a land facility, may also be provided. The remote location then is made capable of controlling the operation of the chemical injection units of the system of the present invention.

In one embodiment, the present invention provides a subsea additive injection system for treating formation fluids. In one mode, the system injects, monitors and controls the supply of additives into fluids recovered through subsea production wellbores. The system can include a surface facility having a supply unit for supplying additives to a chemical injection unit located at a subsea location.

The chemical injection unit includes a pump and a controller. The pump supplies, under pressure, a selected additive from a chemical supply unit into the subsea wellbore via a suitable supply line. In one embodiment, one or more additives are pumped from an umbilical disposed on the outside of a riser extending to a surface facility. In another embodiment, the additives are supplied from one or more subsea tanks. The controller at a seabed location determines additive flow rate and controls the operation of the pump according to stored parameters in the controller. The subsea controller adjusts the flow rate of the additive to the wellbore to achieve the desired level of chemical additives.

The system of the present invention may be configured for multiple production wells. In one embodiment, such a system includes a separate pump, a fluid line and a subsea controller for each subsea well. Alternatively, a suitable

common subsea controller may be provided to communicate with and to control multiple wellsite pumps via addressable signaling. A separate flow meter for each pump provides signals representative of the flow rate for its associated pump to the onsite common controller. The seabed controller at least periodically polls each flow meter and performs the above-described functions. If a common additive is used for a number of wells, a single additive source may be used. A single or common pump may also be used with a separate control valve in each supply line that is controlled by the controller to adjust their respective flow rates. The additive injection of the present invention may also utilize a mixer wherein different additives are mixed or combined at the wellsite and the combined mixture is injected by a common pump and metered by a common meter. The seabed controller controls the amounts of the various additives into the mixer.

The additive injection system may further include a plurality of sensors downhole which provide signals representative of one or more parameters of interest. Parameter of interest can include the status, operation and condition of equipment (e.g., valves) and the characteristics of the produced fluid, such as the presence or formation of sulfites, hydrogen sulfide, paraffin, emulsion, scale, asphaltenes, hydrates, fluid flow rates from various perforated zones, flow rates through downhole valves, downhole pressures and any other desired parameter. The system may also include sensors or testers that provide information about the characteristics of the produced fluid. The measurements relating to these various parameters are provided to the wellsite controller which interacts with one or more models or programs provided to the controller or determines the amount of the various additives to be injected into the wellbore and/or into a subsea fluid treatment unit and then causes the system to inject the correct amounts of such additives. In one aspect, the system continuously or periodically updates the models based on the various operating conditions and then controls the additive injection in response to the updated models. This provides a closed-loop system wherein static or dynamic models may be utilized to monitor and control the additive injection process. The additives injected using the present invention are injected in very small amounts. Preferably, the flow rate for an additive injected using the present invention is at a rate such that the additive is present at a concentration of from about 1 parts per million (ppm) to

about 10,000 ppm in the fluid being treated.

The surface facility supports subsea chemical injection and monitoring activities. In one embodiment, the surface facility is an offshore rig that provides power and has a chemical supply that provides additives to one or more injection units. This embodiment includes an offshore platform having a chemical supply unit, a production fluid processing unit, and a power supply. Disposed outside of the riser are a power transmission line and umbilical bundle, which transfer electrical power and additives, respectively, from the surface facility to the subsea chemical injection unit. The umbilical bundle can include metal conductors, fiber optic wires, and hydraulic lines.

In another embodiment, the surface facility includes a relatively stationary buoy and a mobile service vessel. The buoy provides access to an umbilical adapted to convey chemicals to the subsea chemical injection unit. In one embodiment, the buoy includes a hull, a port assembly, a power unit, a transceiver, and one or more processors. The umbilical includes an outer protective riser, tubing adapted to convey additives, power lines, and data transmission lines having metal conductors and/or fiber optic wires. The power lines transmit energy from the power unit to the chemical injection unit and/or other subsea equipment. In certain embodiments, the transceiver and processors cooperate to monitor subsea operating conditions via the data transmission lines. Sensors may be positioned in the chemical supply unit, the production fluid processing unit, and the riser. The signals provided by these sensors can be used to optimize operation of the chemical injection unit. The service vessel includes a surface chemical supply unit and a docking station or other suitable equipment for engaging the buoy and/or the port. During deployment, the service vessel visits one or more buoys, and, pumps one or more chemicals to the chemical injection unit via the port and umbilical.

Examples of the more important features of the invention have been summarized rather broadly in order that the detailed description thereof that follows may be better understood and in order that the contributions they represent to the art may be appreciated. There are, of course, additional features of the invention that will be described hereinafter and which will form the subject of the claims appended hereto.

BRIEF DESCRIPTION OF THE DRAWINGS

For a detailed understanding of the present invention, reference should be made to the following detailed description of the one mode embodiments, taken in conjunction with the accompanying drawings, in which like elements have been given like numerals, wherein:

Figure 1 is a schematic illustration of an offshore production facility having an additive injection and monitoring system made according to one embodiment of the present invention;

Figure 2 is a schematic illustration of a additive injection and monitoring system according to one embodiment of the present invention;

Figure 3 shows a functional diagram depicting one embodiment of the system for controlling and monitoring the injection of additives into multiple wellbores, utilizing a central controller on an addressable control bus;

Figure 4 is a schematic illustration of a wellsite additive injection system which responds to in-situ measurements of downhole and surface parameters of interests according to one embodiment of the present invention;

Figure 5A is a schematic illustration of a surface facility having a platform according to one embodiment of the present invention; and

Figure 5B is a schematic illustration of a surface facility having a service vessel and buoy made according to one embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring initially to **Figure 1**, there is schematically shown a chemical injection and monitoring system **100** (hereafter "system **100**") made in accordance with the present invention. The system **100** may be deployed in conjunction with a surface facility **110** located at a water's surface **112** that services one or more subsea production wells **60** residing in a seabed **116**. Conventionally, each well **60** includes a well head **114** and related equipment positioned over a wellbore **118** formed in a subterranean formation **120**. The well bores **118** can have one or more production zones **122** for draining hydrocarbons from the formation **120** ("produced fluids" or "production fluid"). The production fluid is conveyed to a surface collection facility (e.g., surface facility **110** or separate structure) or a subsea collection and/or processing facility **126** via a line

127. The fluid may be conveyed to the surface facility **110**-via a line **128** in an untreated state or, preferably, after being processed, at least partially, by the production fluid-processing unit **126.**

The system **100** includes a surface chemical supply unit **130** at the surface facility **110**, a single or multiple umbilicals **140** disposed inside or outside of the riser **124**, one or more sensors **S**, a subsea chemical injection unit **150** located at a remote subsea location (*e.g.*, at or near the seabed **116**), and a controller **152**. The sensors **S** are shown collectively and at representative locations; *i.e.*, water surface, wellhead, and wellbore. In some embodiments, the system **100** can include a power supply **153** and a fluid-processing unit **154** positioned on the surface facility **110**. The umbilical **140** can include hydraulic lines **140h** for supplying pressurized hydraulic fluid, one or more tubes for supplying additives **140c**, and power/data transmission lines **140b** and **140d** such as metal conductors or fiber optic wires for exchanging data and control signals. The chemical injection unit can be sealed in a water-tight enclosure.

During production operations, in one embodiment the surface chemical supply unit **130** supplies (or pumps) one or more additives to the chemical injection unit **150**. The surface chemical supply unit **130** may include multiple tanks for storing different chemicals and one or more pumps to pump chemicals to the subsea tank **131**. This supply of additives may be continuous. Multiple subsea tanks may be used to store a pre-determined amount of each chemical. These tanks **131** then are replenished as needed by the surface supply unit **130**. The chemical injection unit **150** selectively injects these additives into the production fluid at one or more pre-determined locations. In a one mode of operation, the controller **152** receives signals from the sensors **S** regarding a parameter of interest which may relate to a characteristic of the produced fluid. The parameters of interest can relate, for example, to environmental conditions or the health of equipment. Representative parameters include but are not limited to temperature, pressure, flow rate, a measure of one or more of hydrate, asphaltene, corrosion, chemical composition, wax or emulsion, amount of water, and viscosity. Based on the data provided by the sensors **S**, the controller **152** determines the appropriate amount of one or more additives needed to maintain a desired or pre-determined flow rate or other operational criteria and alters the operation of the chemical injection unit **150** accordingly. A surface controller

152S may be used to provide signals to the subsea controller **152** to control the delivery of additives to the wellbore **118** and/or the processing unit **126**.

Referring now to **Figure 2**, there shown a schematic diagram of a subsea chemical injection system **150** according to one embodiment of the present invention. The system **150** is adapted to inject additives **13a** into the wellbore **118** and/or into a subsea surface treatment or processing unit **126.** The system **150** is further adapted to monitor pre-determined conditions (discussed later) and alter the injection process accordingly. The wellbore **118** is shown as a production well using typical completion equipment. The wellbore **118** has a production zone **122** that includes multiple perforations **54** through the formation **120.** Formation fluid **56** enters a production tubing **59** in the well **118** via perforations **54** and passages **62**. A screen **58** in the annulus **51** between the production tubing **59** and the formation **120** prevents the flow of solids into the production tubing **59** and also reduces the velocity of the formation fluid entering into the production tubing **59** to acceptable levels. An upper packer **64a** above the perforations **54** and a lower packer **64b** in the annulus **51** respectively isolate the production zone **122** from the annulus **51a** above and annulus **51b** below the production zone **122.** A flow control valve **66** in the production tubing **59** can be used to control the fluid flow to the seabed surface **116**. A flow control valve **67** may be placed in the production tubing **62** below the perforations **54** to control fluid flow from any production zone below the production zone **122.**

A smaller diameter tubing **68**, may be used to carry the fluid from the production zones to the subsea wellhead **114**. The production well **118** usually includes a casing **40** near the seabed surface **116.** The wellhead **114** includes equipment such as a blowout preventor stack **44** and passages **14** for supplying fluids into the wellbore **118.** Valves (not shown) are provided to control fluid flow to the seabed surface **116**. Wellhead equipment and production well equipment, such as shown in the production well **118**, are well known and thus are not described in greater detail.

Referring still to **Figure 2**, in one aspect of the present invention, the desired additive **13a** is injected into the wellbore **118** via an injection line **14** by a suitable pump, such as a positive displacement pump **18** ("additive pump"). In one aspect, the additive **13a** flows through the line **14** and discharges into the production tubing **60** near the production zone **122** via inlets or passages **15**.

The same or different injection lines may be used to supply additives to different production zones. In **Figure 2**, line **14** is shown extending to a production zone below the zone **122.** Separate injection lines allow injection of different additives at different well depths. The additives **13a** may be supplied from a tank **131** that is periodically filled via the supply line **140**. Alternatively, the additives **13a** may be supplied directly from the surface chemical supply **130** via supply line **140c**. The tank **131** may include multiple compartments and may be replaceable tanks which is periodically replaced. A level sensor S_L can provide to the controller **152** or **152S** (Fig. 1) indication of the additive remaining in the tank **131**. When the additive level falls below a predetermined level, the tank is replenished or replaced. Alternatively a remotely operated vehicle **700** ("ROV") may be used to replenish the tank via feed line **140**. The ROV **700** attaches to the supply line and replenishes the tank **131**. Other conventional methods may be used to replace tank **131**. Replaceable tanks are preferably quick disconnect types (e.g., mechanical, hydraulic, etc.). Of course, certain embodiments can include a combination of supply arrangements.

In one embodiment, a suitable high-precision, low-flow, flow meter **20** (such as gear-type meter or a nutating meter) measures the flow rate through line **14** and provides signals representative of the flow rate. The pump **18** is operated by a suitable device **22** such as a motor. The stroke of the pump **18** defines fluid volume output per stroke. The pump stroke and/or the pump speed are controlled, e.g., by a 4 - 20 milliamperes control signal to control the output of the pump **18**. The control of air supply controls a pneumatic pump. Any suitable pump and monitoring system may be used to inject additives into the wellbore **118**.

In one embodiment of the present invention, a seabed controller **80** controls the operation of the pump **18** by utilizing programs stored in a memory **91** associated with the subsea controller **80**. The subsea controller **80** preferably includes a microprocessor **90**, resident memory **91** which may include read only memories (ROM) for storing programs, tables and models, and random access memories (RAM) for storing data. The microprocessor **90** utilizes signals from the flow meter **20** received via line **21** and programs stored in the memory **91** to determine the flow rate of the additive. The wellsite controller **80** can be programmed to alter the pump speed, pump stroke or air supply to deliver the

desired amount of the additive **13a**. The pump speed or stroke, as the case may be, is increased if the measured amount of the additive injected is less than the desired amount and decreased if the injected amount is greater than the desired amount.

The seabed controller **80** preferably includes protocols so that the flow meter **20**, pump control device **22**, and data links **85** made by different manufacturers can be utilized in the system **150**. In the oil industry, the analog output for pump control is typically configured for 0-5 VDC or 4-20 milliampere (mA) signal. In one mode, the subsea controller **80** can be programmed to operate for such output. This allows for the system **150** to be used with existing pump controllers. A power unit **89** provides power to the controller **80**, converter **83** and other electrical circuit elements. The power unit **89** can include an AC power unit, an onsite generator, and/or an electrical battery that is periodically charged from energy supplied from a surface location. Alternatively, power may be supplied from the surface via a power line disposed along the riser **124** (discussed in detail below).

Still referring to **Figure 2**, the produced fluid **69** received at the seabed surface **116** may be processed by a treatment unit or processing unit **126.** The seabed processing unit **126** may be of the type that processes the fluid **69** to remove solids and certain other materials such as hydrogen sulfide, or that processes the fluid **69** to produce semi-refined to refined products. In such systems, it is desired to periodically or continuously inject certain additives. Thus, the system **150** shown in **Figure 1** can be used for injecting and monitoring additives **13b** into the processing unit **126.** These additives may be the same or different from the additives injected into the wellbore **118**. These additives **13b** are suitable to process the produced wellbore fluid before transporting it to the surface. In configuration of **Fig. 2**, the same chemical injection unit may be utilized to pump chemicals in multiple wellbores, subsea pipelines and/or subsea processing units.

In addition to the flow rate signals **21** from the flow meter **20**, the seabed controller **80** may be configured to receive signals representative of other parameters, such as the rpm of the pump **18**, or the motor **22** or the modulating frequency of a solenoid valve. In one mode of operation, the wellsite controller **80** periodically polls the meter **20** and automatically adjusts the pump controller

22 via an analog input **22a** or alternatively via a digital signal of a solenoid controlled system (pneumatic pumps). The controller **80** also can be programmed to determine whether the pump output, as measured by the meter **20**, corresponds to the level of signal **22a**. This information can be used to determine the pump efficiency. It can also be an indication of a leak or another abnormality relating to the pump **18**. Other sensors **94**, such as vibration sensors, temperature sensors may be used to determine the physical condition of the pump **18**. Sensors **S** that determine properties of the wellbore fluid can provide information of the treatment effectiveness of the additive being injected. Representative sensors include, but are not limited to, a temperature sensor, a viscosity sensor, a fluid flow rate sensor, a pressure sensor, a sensor to determine chemical composition of the production fluid, a water cut sensor, an optical sensor, and a sensor to determine a measure of at least one of asphaltene, wax, hydrate, emulsion, foam or corrosion. The information provided by these sensors can then be used to adjust the additive flow rate as more fully described below in reference to **Figure 3** and **4**.

It should be understood that a relatively small amount of additives are injected into the production fluid during operation. Accordingly, rather considerations such as precision in dispensing additives can be more relevant than mere volumetric capacity. Preferably, the flow rate for an additive injected using the present invention is at a rate such that the additive is present at a concentration of from about 1 parts per million (ppm) to about 10,000 ppm in the fluid being treated. More preferably, the flow rate for an additive injected using the present invention is at a rate such that the additive is present at a concentration of from about 1 ppm to about 500 ppm in the fluid being treated. Most preferably the flow rate for an additive injected using the present invention is at a rate such that the additive is present at a concentration of from about 10 ppm to about 400 ppm in the fluid being treated.

As noted above, it is common to drill several wellbores from the same location. For example, it is common to drill 10-20 wellbores from a single offshore platform. After the wells are completed and producing, a separate subsea pump and meter are installed to inject additives into each such wellbore.

Figure 3 shows a functional diagram depicting a system **200** for controlling and monitoring the injection of additives into multiple wellbores **202a-**

202m according to one embodiment of the present invention. In the system configuration of **Figure3**, a separate pump supplies an additive via supply lines **140** from a surface chemical supply **130 (Fig. 1)** to each of the wellbores **202a-202m**. For example, pump **204a** supplies an additive and the meter **208a** measures the flow rate of the additive into the wellbore **202a** and provides corresponding signals to a central wellsite controller **240**. The wellsite controller **240** in response to the flow meter signals and the programmed instructions controls the operation of pump control device or pump controller **210a** via a bus **241** using addressable signaling for the pump controller **210a**. Alternatively, the wellsite controller **240** may be connected to the pump controllers via a separate line. The wellsite controller **240** also receives signal from sensor **S1a** associated with pump **204a** via line **212a** and from sensor **S2a** associated with the pump controller **210a** via line **212a**. Such sensors may include rpm sensor, vibration sensor or any other sensor that provides information about a parameter of interest of such devices. Additives to the wells **202b-202m** are respectively supplied by pumps **204b-204m** from sources **206b-206m**. Pump controllers **210b-210m** respectively control pumps **204b-204m** while flow meters **208b-208m** respectively measure flow rates to the wells **202b-202m**. Lines **212b-212m** and lines **214b-214m** respectively communicate signals from sensor S_{1b}-S_{1m} and S_{2b}-S_{2m} to the central controller **240**. The controller **240** utilizes memory **246** for storing data in memory **244** for storing programs in the manner described above in reference to system **100** of **Figure 1**. The individual controllers communicate with the sensors, pump controllers and remote controller via suitable corresponding connections.

The central wellsite controller **240** controls each pump independently. The controller **240** can be programmed to determine or evaluate the condition of each of the pumps **204a-204m** from the sensor signals S_{1a}-S_{1m} and S_{2a}-S_{2m}. For example the controller **240** can be programmed to determine the vibration and rpm for each pump. This can provide information about the effectiveness of each such pump.

Figure 4 is a schematic illustration of a closed-loop additive injection system **300** which responds to measurements of downhole and surface parameters of interest according to one embodiment of the present invention. Certain elements of the system **300** are common with the system **150** of **Figure**

2. For convenience, such common elements have been designated in **Figure 4** with the same numerals as specified in **Figure 2**.

The well **118** in **Figure 4** further includes a number of downhole sensors $\mathbf{S_{3a}}$-$\mathbf{S_{3m}}$ for providing measurements relating to various downhole parameters. The sensors may be is located at wellhead over the at least one wellbore, in the wellbore, and/or in a supply line between the wellhead and the subsea chemical injection unit. Sensor $\mathbf{S_{3a}}$ provide a measure of chemical and physical characteristics of the downhole fluid, which may include a measure of the paraffins, hydrates, sulfides, scale, asphaltenes, emulsion, etc. Other sensors and devices $\mathbf{S_{3m}}$ may be provided to determine the fluid flow rate through perforations **54** or through one or more devices in the well **118.** These sensors may be distributed along the wellbore and may include fiber optic and other sensors. The signals from the sensors may be partially or fully processed downhole or may be sent uphole via signal/date lines **302** to a wellsite controller **340**. In the configuration of **Figure 3**, a common central control unit **340** is preferably utilized. The control unit is a microprocessor-based unit and includes necessary memory devices for storing programs and data.

The system **300** may include a mixer **310** for mixing or combining at the wellsite a plurality of **additive #1 - additive #m** stored in sources **313a-312m** respectively. The sources 313a-**312m** are supplied with additives via supply line **140**. In some situations, it is desirable to transport certain additives in their component forms and mix them at the wellsite for safety and environmental reasons. For example, the final or combined additives may be toxic, although while the component parts may be non-toxic. Additives may be shipped in concentrated form and combined with diluents at the wellsite prior to injection into the well **118.** In one embodiment of the present invention, additives to be combined, such as additives **additive #1-additive #m** are metered into the mixer by associated pumps **314a-314m**. Meters **316a-316m** measure the amounts of the additives from sources **312a-312m** and provide corresponding signals to the control unit **340**, which controls the pumps **314a-314m** to accurately dispense the desired amounts into the mixer **310**. A pump **318** pumps the combined additives from the mixer **310** into the wellbore **118**, while the meter **320** measures the amount of the dispensed additive and provides the measurement signals to the controller **340**. A second additive required to be injected into the well **118** may be

stored in the source tank **131**, from which source a pump **324** pumps the required amount of the additive into the well. A meter **326** provides the actual amount of the additive dispensed from the source tank **131**to the controller **340**, which in turn controls the pump **324** to dispense the correct amount.

The wellbore fluid reaching the surface may be tested on site with a testing unit **330**. The testing unit **330** provides measurements respecting the characteristics of the retrieved fluid to the central controller **340**. The central controller utilizing information from the downhole sensors S_{3a}-S_{3m}, the tester unit data and data from any other surface sensor (as described in reference to **Figure 2**) computes the effectiveness of the additives being supplied to the well **118** and determine therefrom the correct amounts of the additives and then alters the amounts, if necessary, of the additives to the required levels. The controller **340** may also receive commands from the surface controller **152s** and/or a remote controller **152s** to control and/or monitor the wells **202a-202m**

Thus, the system of the present invention at least periodically monitors the actual amounts of the various additives being dispensed, determines the effectiveness of the dispensed additives, at least with respect to maintaining certain parameters of interest within their respective predetermined ranges, determines the health of the downhole equipment, such as the flow rates and corrosion, determines the amounts of the additives that would improve the effectiveness of the system and then causes the system to dispense additives according to newly computed amounts. The models **344** may be dynamic models in that they are updated based on the sensor inputs.

The system of the present invention can automatically take broad range of actions to assure proper flow of hydrocarbons through pipelines, which not only can minimize the formation of hydrates but also the formation of other harmful elements such as asphaltenes. Since the system **300** is closed loop in nature and responds to the in-situ measurements of the characteristics of the treated fluid and the equipment in the fluid flow path, it can administer the optimum amounts of the various additives to the wellbore or pipeline to maintain the various parameters of interest within their respective limits or ranges.

Referring now to Figure **5A,** there is shown one embodiment of a surface facility and a remote control station for supporting and controlling the subsea chemical injection and monitoring activities of a subsea chemical injection

system, such as system **150** of **Figure 1**. The Figure **5A** surface facility **500** can provide power and additives as needed to one or more subsea chemical injection units **150 (Fig. 1)**. Also, the surface facility **500** includes equipment for processing, testing and storing produced fluids. A one mode surface facility **500** includes an offshore platform or rig or a vessel **510** having a chemical supply unit **520**, a production fluid processing unit **530**, a power supply **540**, a controller **532** and may include a remote controller **533** via a satellite or other long distance means. The chemical supply unit **520** may include separate tanks for each type of chemical desired to be supplied therefrom to the chemical injection unit **150 (Fig. 1)** via a supply line or umbilical bundle **522** that is disposed inside or outside of a riser **550**. Each chemical/additive can either have a dedicated supply line (*i.e.*, multiple lines) or share one or more supply lines. Likewise, the umbilical bundle **522** can include power and/or data transmission lines **544** for transmitting power from the power supply **540** to the subsea components of the system **100** and transmitting data and control signals between the surface controller **532** and the subsea controller **152 (Fig. 1)**. Suitable lines **544** include fiber optic wires and metal conductors adapted to convey data, electrical signals and power. The processing unit **530** receives produced fluid from the well head **114 (Fig. 1)** via the riser **550**. Sensors S_4 may be positioned in the chemical supply unit **520**, the production fluid processing unit **530**, and the riser **550** (sensors $S_{4a\text{-}c}$, respectively). Sensors **S4c** may be distributed along the riser and/or umbilical to provide signals representative of fluid flow, physical and chemical characteristics of the additives and production fluid and environmental conditions. As explained earlier, measurement provided by these sensors can be used to optimize operation of the chemical injection unit **150 (Fig. 1)**. It will be appreciated that a single surface facility as shown in **Figure 5A** may be used to service multiple subsea oilfields.

Referring now to **Figure 5B,** there is shown another embodiment of a surface facility. The **Figure 5B** surface facility **600** supplies additives on-demand or on a pre-determined basis to the chemical injection unit **150 (Fig. 1)** without using a dedicated chemical supply unit. A one mode surface facility **600** includes a buoy **610** and a service vessel **630**.

The buoy **610** provides a relatively stationary access to an umbilical **611** and a riser **612** adapted to convey power, data, control signals, and chemicals to

the chemical injection unit **150** (**Fig. 1**). The buoy **610** includes a hull **614**, a port assembly **616**, a power unit **618**, a transceiver **620**, and one or more processors **624**. The hull **614** is of a conventional design and can be fixed, floating, semi-submersed, or full submersed. In certain embodiments, the hull **614** can include known components such as ballast tanks that provide for selective buoyancy. The port **616** is suitably disposed on the hull **614** and is in fluid communication with the conduit **612**. The conduit **612** includes an outer protective riser **612a** and the umbilical **611**, which can include single or multiple tubing **612b** adapted to convey chemicals and additives, power lines **612c**, and data transmission lines **612d**. The power lines **612d** transmit stored or generated power of the power unit **618** to the chemical injection unit (**Fig. 1**) and/or other subsea equipment. The power lines **612d** can also include hydraulic lines for conveying hydraulic fluid to subsea equipment. Power may be generated by a conventional generator **622** and/or stored in batteries **621** which can be charged via a solar power generation system **619**. The transceiver **620** and processors **624** cooperate to monitor subsea operating conditions via the data transmission lines **612d**. The data transmission lines can use metal conductors or fiber optic wires. In certain embodiments, the transceiver **620** and processors **624** can determine whether any subsea equipment is malfunctioning or whether the chemical injection unit **130** (**Fig. 1**) will exhaust its supply of one or more additives. Upon making such a determination, the transceiver **620** can be used to transmit this determination to a control facility (not shown). Sensors $\mathbf{S_5}$ may be positioned in the production fluid processing unit **640** (sensor $\mathbf{S_{5a}}$), the riser **612** (sensor $\mathbf{S_{5b}}$), or other suitable location. As explained earlier, measurement provided by these sensors can be used to optimize operation of the chemical injection unit **130** (**Fig. 1**). The subsea chemical injection unit can be sealed in a water-tight enclosure.

The service vessel **630** includes a surface chemical supply unit **632** and a suitable equipment (not shown) for engaging the buoy **610** and/or the port **616**. The service vessel **630** may be self-powered (*e.g.*, a ship or a towed structure). During deployment, the service vessel **630** visits one or more buoys **610** on a determined schedule or on an as-needed basis. Upon making up a connection to the port **616**, one or more chemicals is pumped down to the chemical storage tank **130** (**Fig. 1**) via the tubing **612b**. After the pumping operation is complete, the buoy **610** is released and the service vessel **630** is free to visit other buoys

610. It should be appreciated that the buoy **630** according to the present invention are less expensive than conventional offshore platforms.

Produced fluid from the well head **114** (**Fig. 1**) is conveyed via a line **632** to a fluid processing unit **640**. The processed produced fluids are then transferred to a surface or subsea collection facility via line **642**.

Referring to **Figure 1, 5A** and **5B,** the system may further include devices that heat production fluid in subsea lines, such as line **127**. The power for heating devices (**189**) can be tapped from power supplied by the surface unit to the subsea chemical injection unit **150** or to any other subsea device, such as wellhead valves. The sensors **S** monitor the condition of the production fluid. The system of **Figures 1-5** controls and monitors the injection of chemicals into subsea wellbores **118.** A subsea chemical injection alone can control and monitor the injection of chemicals into wellbores **118** and underwater processing facility **126**. The system can also monitor the fluid carry lines **127**. The unit **150** can control and monitor the chemical injection in response to various sensor measurements or according to programmed instructions. The chemical sensor in the system provides information from various places along the wellbore **118**, pipe**127**, fluid processing unit **126**, and riser **124** or **150**. The other sensors provide information about the physical or environmental conditions. The subsea controller **152**, the surface controller **152s** and the remote controller **152s** cooperate with each other and in response to one or more sensor measurements in parameters of interest control and/or monitor the operation of the entire system shown in **Figs. 1-5**.

While the foregoing disclosure is directed to the one mode embodiments of the invention, various modifications will be apparent to those skilled in the art. It is intended that all variations within the scope and spirit of the appended claims be embraced by the foregoing disclosure.

WHAT IS CLAIMED IS:

1. A system for injecting one or more additives into production fluid produced by at least one subsea well, the system comprising:
   a) a surface chemical supply unit for supplying at least one chemical to a selected subsea location;
   b) at least one chemical supply line for carrying the at least one chemical from the surface to the selected subsea location; and
   c) a subsea chemical injection unit at the selected subsea location receiving the at least one chemical from the surface chemical supply unit and selectively injecting the at least one chemical into the production fluid.

2. The system of claim 1 further comprising a controller that controls the amount of the at least one chemical injected in response to at least one parameter of interest.

3. The system of claim 1 wherein the parameter of interest is one of (i) temperature, (ii) pressure, (iii) flow rate, (iv) a measure of one of hydrate, asphaltene, corrosion, chemical composition, wax or emulsion, (v) amount of water, and (vi) viscosity.

4. The system of claim 3 further comprising at least one sensor for providing information about the at least one parameter interest, said at least one sensor being selected from a group consisting of a temperature sensor, a viscosity sensor, a fluid flow rate sensor, a pressure sensor, a sensor to determine chemical composition of the production fluid, a water cut sensor, an optical sensor, and a sensor to determine a measure of at least one of asphaltene, wax, hydrate, emulsion, foam and corrosion.

5. The system of claim 1 wherein the subsea chemical injection unit includes a storage unit for storing the at least one chemicals supplied by the surface chemical supply unit.

6. The system of claim 5 wherein the at least one chemical supply line includes a plurality of lines for carrying a plurality of chemical to the subsea chemical injection unit.

7. The system of claim 6 wherein the surface chemical supply unit supplies a plurality of chemicals to the subsea chemical injection unit via the plurality of lines.

8. The system of claim 1 wherein the surface chemical supply unit is located on an offshore rig.

9. The system of claim 1 wherein the surface chemical supply unit includes a buoy at the sea surface and wherein the at least one chemical supply line carries chemicals from the buoy to the selected subsea location.

10. The system of claim 9 wherein the buoy includes a chemical storage unit that is periodically filled.

11. The system of claim 10 wherein the at least one supply line includes a plurality of supply lines, one for each chemical, between the buoy and the selected subsea location.

12. The system of claim 1 wherein the subsea chemical injection unit further comprises a manifold for mixing at least two chemicals prior to injecting the at least two chemicals into the production fluid.

13. The system of claim 1 wherein the subsea chemical injection unit comprises one of a control valve and control pump for controlling the amount of the at least one chemical injected into the at least one subsea well.

14. The system of claim 1 further comprising a subsea power unit for supplying power to the chemical injection unit.

15. The system of claim 14 wherein the subsea power unit includes an electrical battery that is periodically charged from energy supplied from a surface location.

16. The system of claim 1 further comprising a riser for transporting production fluid to the surface and wherein the at least one chemical supply line is located at one of (i) inside the riser, and (ii) outside the riser.

17. The system of claim 1 further comprising a plurality of sensors distributed along a production fluid path.

18. The system of claim 4 wherein the at least one sensor is located at one of (i) wellhead over the at least one wellbore, (ii) in the wellbore, and (iii) in a supply line between the wellhead and the subsea chemical injection unit.

19. The system of claim 1 wherein the at least one subsea well includes a plurality of wells and the subsea chemical injection unit separately supplies the at least one chemical to each said subsea well.

20. The system of claim 1 further comprising a subsea fluid-processing unit receiving the production fluid via a line.

21. The system of claim 1 wherein the subsea chemical injection unit injects the at least one chemical into one of (i) the at least one subsea well, (ii) a subsea fluid processing unit, and (iii) in a subsea pipeline carrying the production fluid.

22. The system of claim 1 further comprising a heating device deployed subsea to heat the production fluid.

23. The system of claim 1 further comprising a surface controller for controlling one of: (i) at least in part the operation of the subsea chemical injection unit and (ii) the supply of the at least one chemical.

24. The system of claim 23 further comprising a remote controller providing command signals to the surface controller to control the injection of the at least one chemical.

25. The system of claim 1 further comprising a plurality of distributed sensors associated with said at least one chemical supply line for providing signals relating to a characteristic of the at least one chemical carried by the at least one chemical supply line.

26. The system of claim 25 wherein the surface chemical supply unit controls the supply of the at least one chemical in response to the signals relating to the characteristic of the at least one chemical in the supply line.

27. The system of claim 22 further comprising a power unit at the surface that provides power to the heating device.

28. The system of claim 20 wherein the processing unit refines at least partially the production fluid.

29. the system of claim 28 further comprising a fluid line carrying processed fluid from the processing unit to the surface.

30. A flow assurance method for fluid produced ("production fluid") by at least one subsea well comprising:

a) providing a surface chemical supply unit at a location remote from the at least one subsea well for supplying at least one chemical to a selected subsea location;

b) providing at least one chemical supply line for carrying the at least one chemical from the surface to the selected subsea location;

c) measuring a parameter of interest relating to a characteristic of the production fluid; and

d) providing a subsea chemical injection unit at the selected subsea location for receiving the at least one chemical from the surface chemical supply unit via the at least one chemical supply line and for selectively injecting the at least one chemical into the production fluid, at least in part in response to the parameter of interest.

31. The method of claim 30 wherein measuring the parameter of interest includes measuring one of temperature, viscosity, fluid flow rate, pressure and chemical composition of the produced fluid, a measure of asphaltene, wax, hydrate, emulsion, foam, corrosion, or water, and an optical property of the production fluid.

32. The method of claim 30 further comprising locating an end of the at least one chemical supply line at a buoy at the water surface.

33. The method of claim 32 further comprising moving the surface chemical supply unit to the buoy to supply the at least one chemical to the subsea chemical injection unit via the at least one supply line.

34. The method of claim 32 wherein the at least one supply line includes a plurality of supply lines and the surface chemical supply unit pumps a separate chemical through each of the plurality of supply lines.

35. The method of claim 30 wherein the subsea chemical injection unit includes: (i) a pump for injecting the at least one chemical into the production fluid; (ii) a flow control valve; and (iii) a controller that controls the flow control valve to control the amount of chemical injected into the at least one subsea well.

36. A system for injecting a chemical into formation fluid produced by at least one subsea well, comprising: (i) a chemical supply system for supplying a desired chemical; and (ii) an underwater chemical injection unit injecting chemical into the formation fluid produced by the at least one subsea well.

37. The system of claim 36 further comprising at least one sensor providing a measurement of a parameter of interest.

38. The system of claim 37 wherein the underwater chemical injection unit includes a controller that controls at least in part the injection of the chemical in response to the parameter of interest.

39. The system of claim 37 wherein the parameter of interest is one of interest in one of: (i) a physical property of the formation stored; (ii) a chemical property of the formation fluid; or (iii) a parameter relating to a device associated with the at least one subsea well.

40. The system of claim 36 wherein the chemical injection unit injects the chemical at one of: (i) at a location within the at least one wellbore, and (ii) at a location at the seabed.

41. The system of claim 37 wherein the chemical supply system includes: (i) an underwater storage tank for storing the chemical therein; and (ii) a chemical supply unit at the sea surface that supplies the chemical to the underwater storage tank.

42. The system of claim 36 wherein the chemical supply system includes an underwater chemical storage tank that is adapted to be one of: (i)

refillable by a remotely operated device and (ii) replaceable via a quick disconnect.

ABSTRACT

A system monitors and controls the injection of additives into formation fluids recovered through a subsea well. The system includes a chemical injection unit and a controller positioned at a remote subsea location. The injection unit uses a pump to supply one or more selected additives from a subsea and/or remote supply unit. The controller operates the pump to control the additive flow rate based on signals provided by sensors measuring a parameter of interest. A one mode system includes a surface facility for supporting the subsea chemical injection and monitoring activities. In one embodiment, the surface facility is an offshore rig that provides power and has a chemical supply that provides additives to one or more injection units. In another embodiment, the surface facility includes a relatively stationary buoy and a mobile service vessel. When needed, the service vessel transfers additives to the chemical injection units via the buoy.

In‿ntor: Christopher Kempson Shaw et al
S‿‿l No.: New Application
Atty Docket: 014-26936-USP1
Express Mail Label No.: EL516647621US

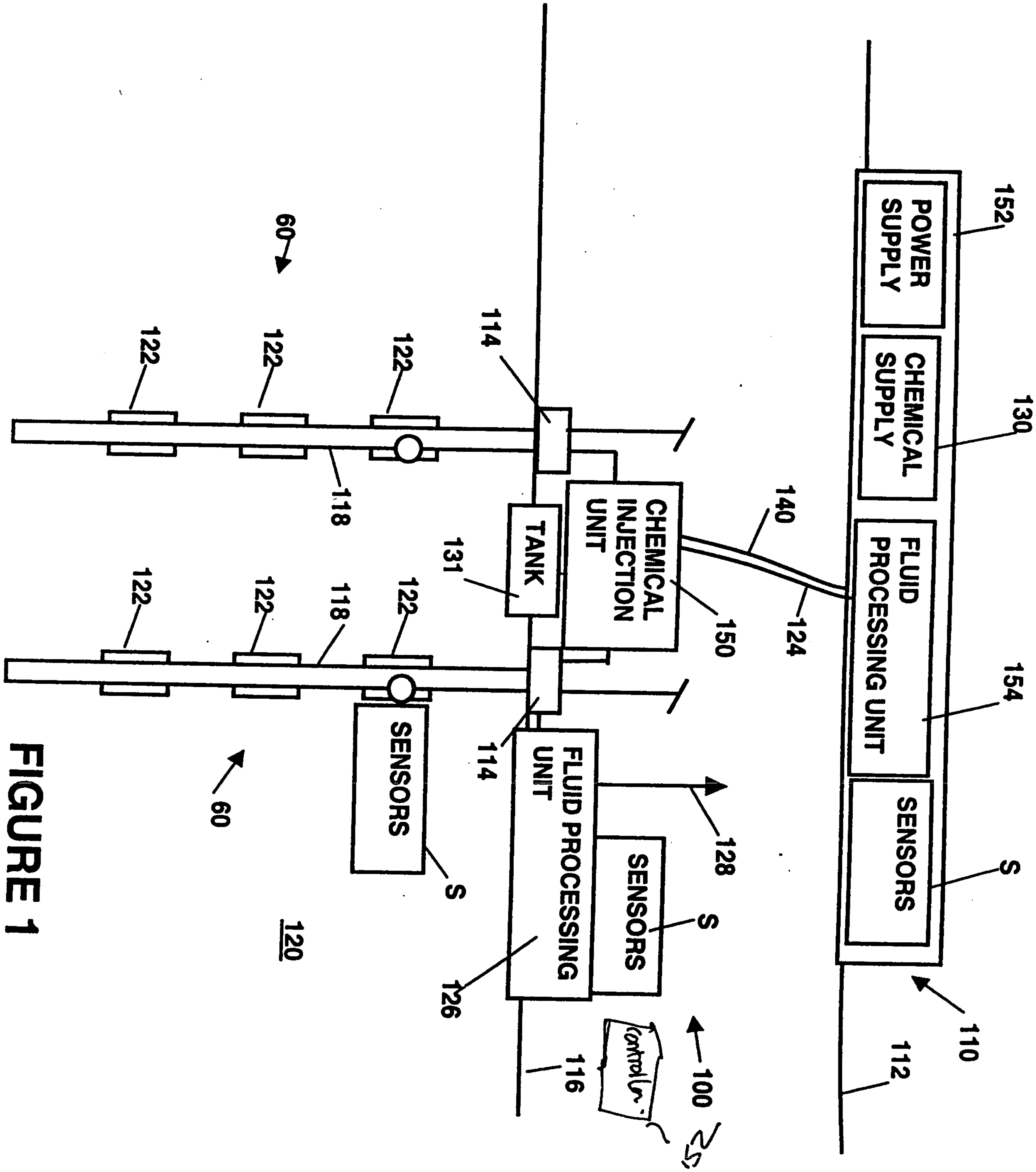

FIGURE 1

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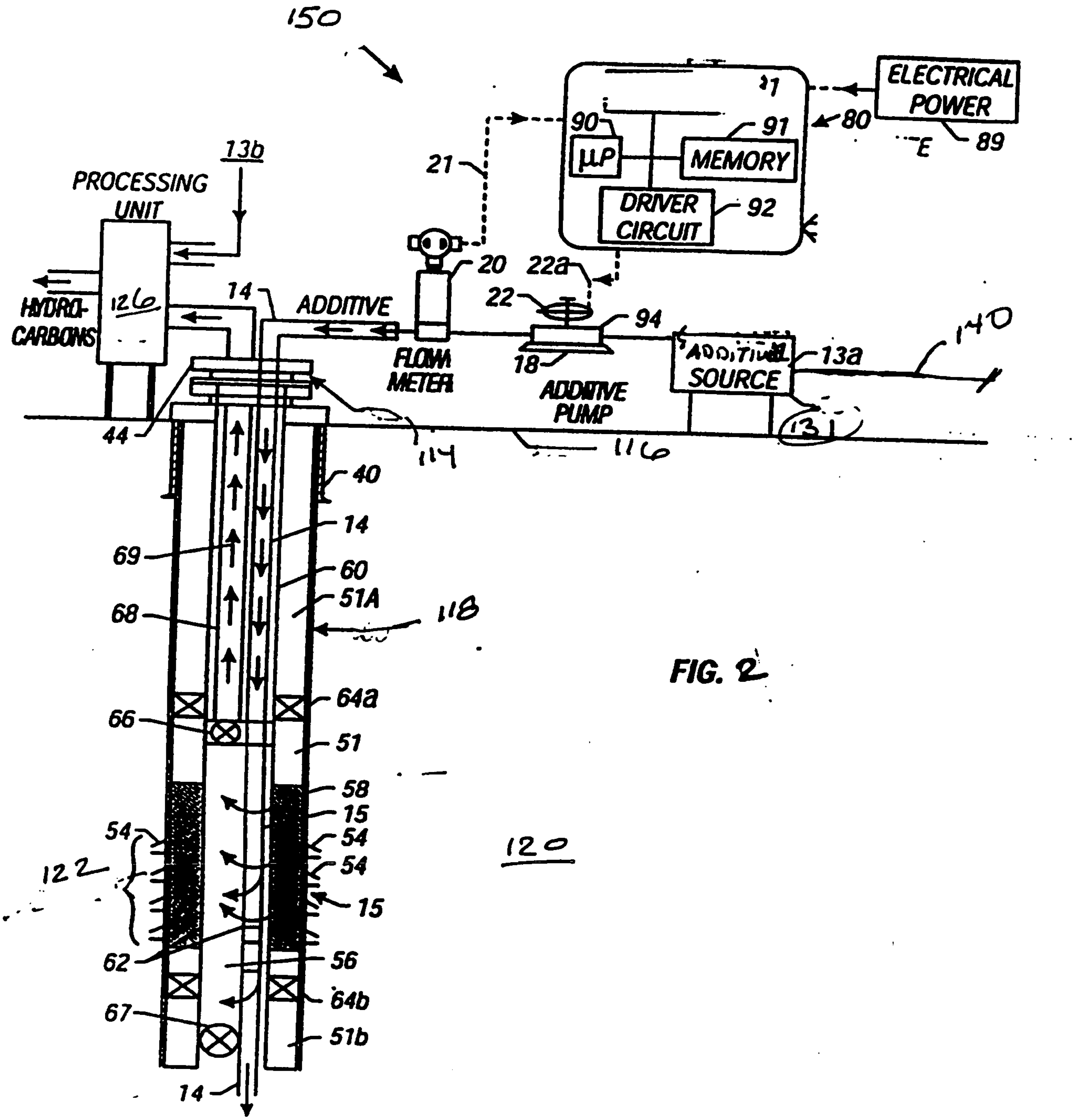

FIG. 2

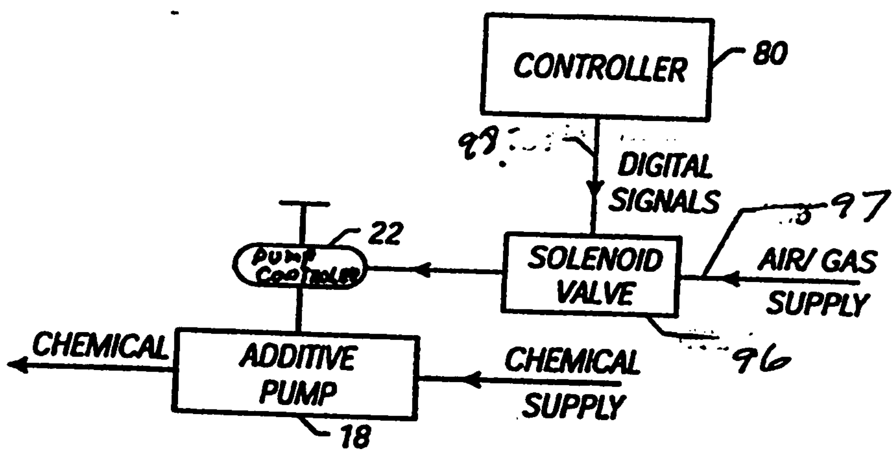
CONTROLLER
80
98
DIGITAL
SIGNALS
97
22
PUMP CONTROLLER
SOLENOID
VALVE
AIR/ GAS
SUPPLY
96
CHEMICAL
ADDITIVE
PUMP
CHEMICAL
SUPPLY
18

FIG. 3

Inven... Christopher Kempson Shaw et al
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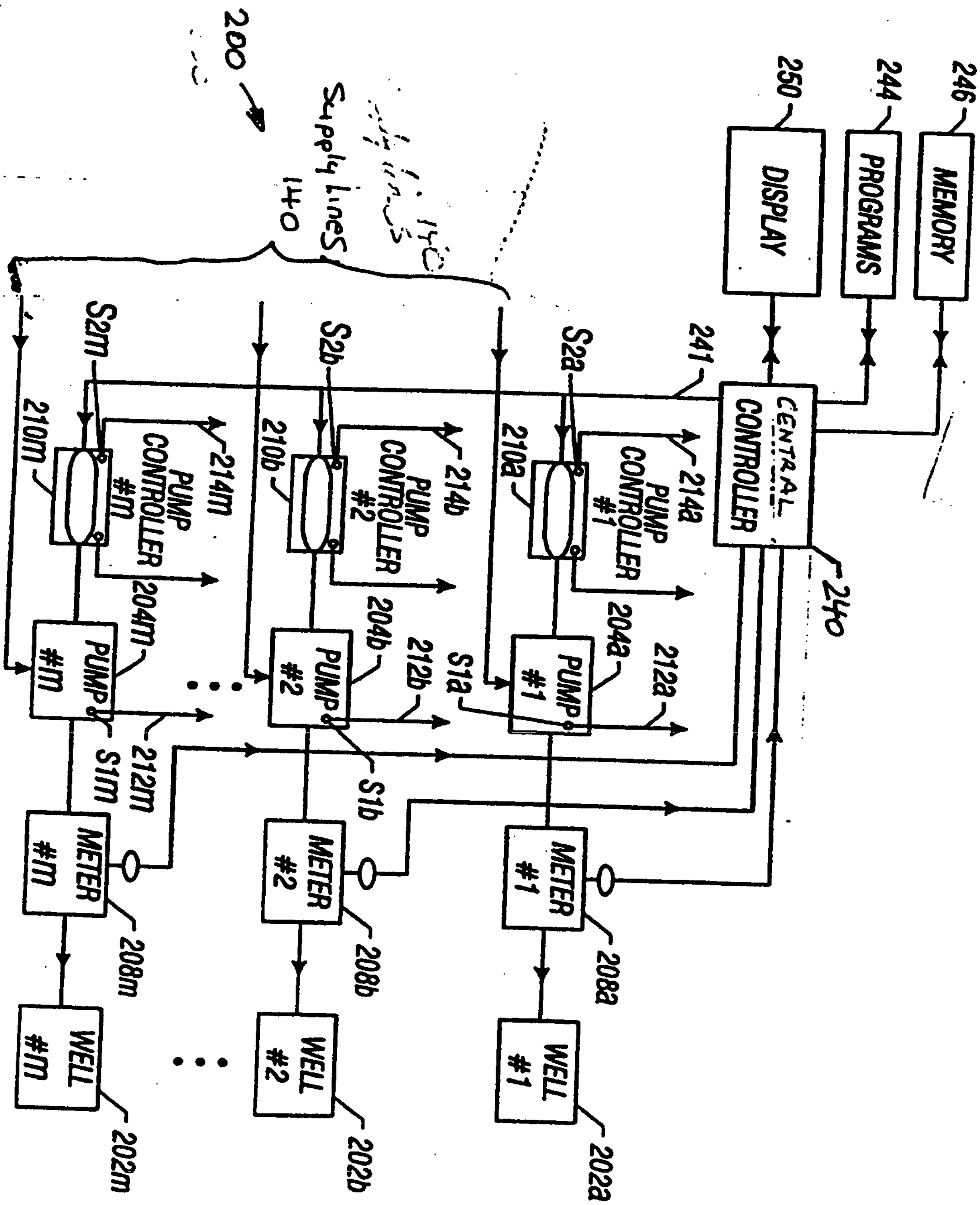

FIGURE 4

Sheet 5 of 7
Inventor: Christopher Kempson Shaw et al
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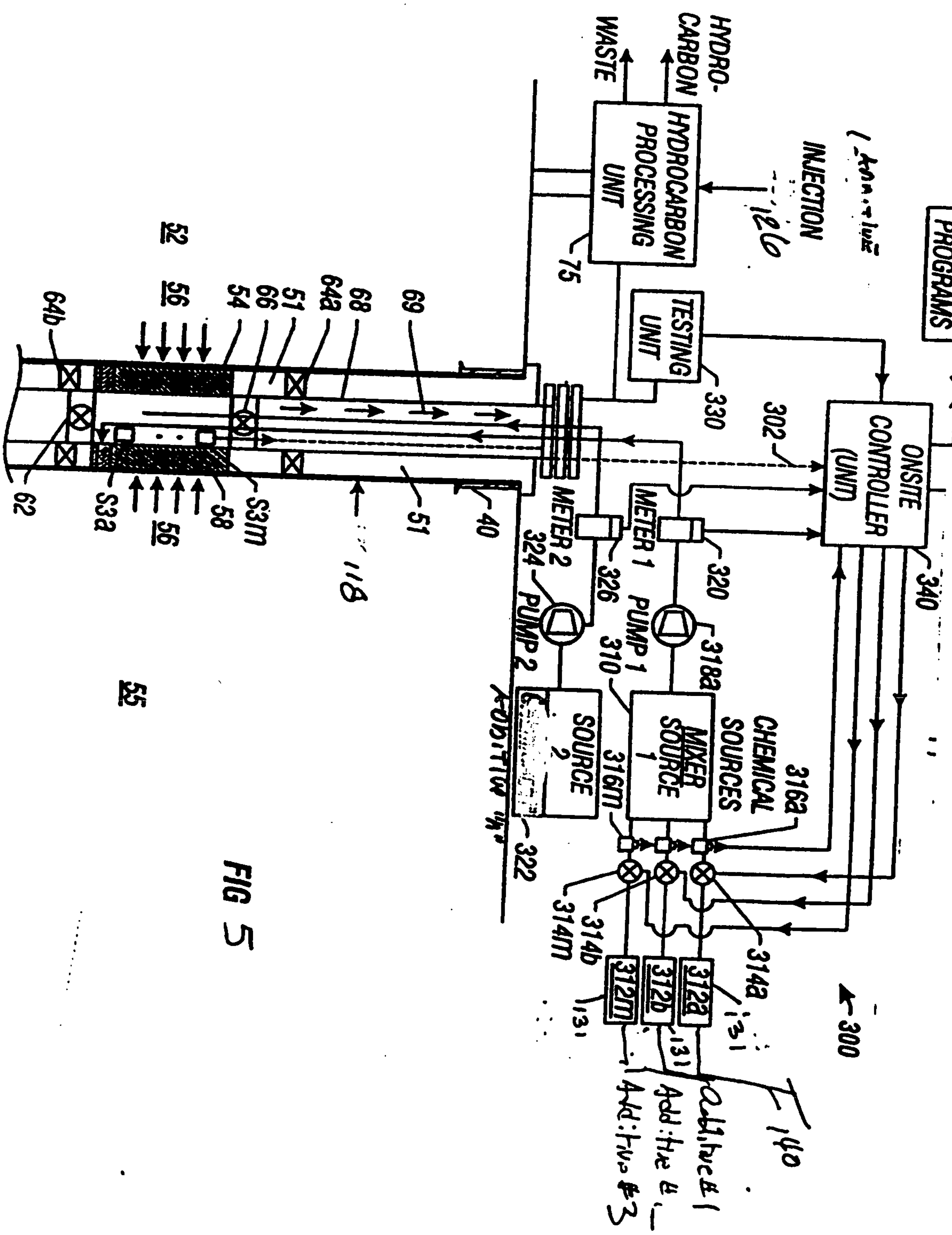

FIG 5

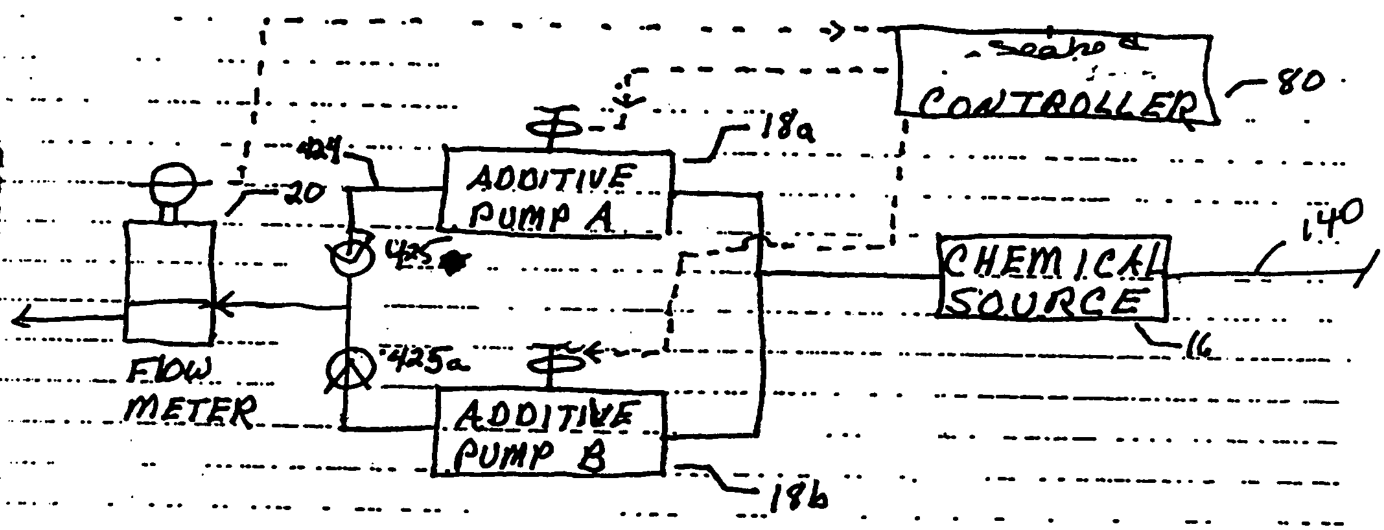
CONTROLLER
80
18a
ADDITIVE PUMP A
20
424
425
CHEMICAL SOURCE
140
16
425a
FLOW METER
ADDITIVE PUMP B
18b

FIGURE 6

Inventor: Christopher Kempson Shaw et al
Serial No.: New Application
Atty Docket: 014-26936-USP1
Express Mail Label No.: EL516647621US

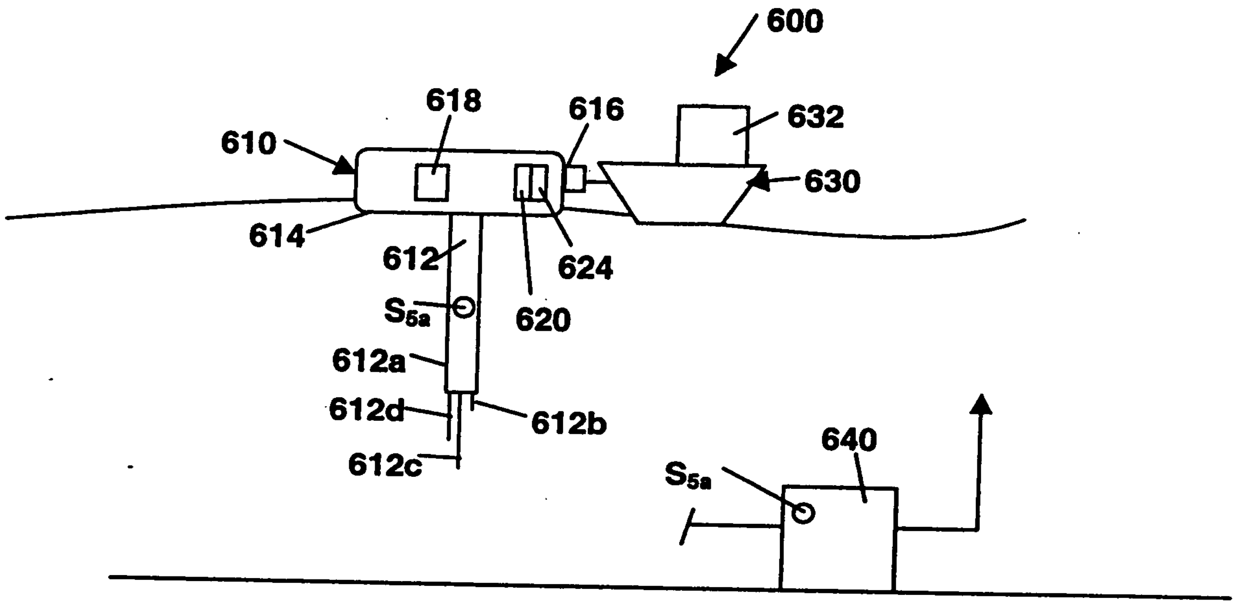

FIGURE 7B

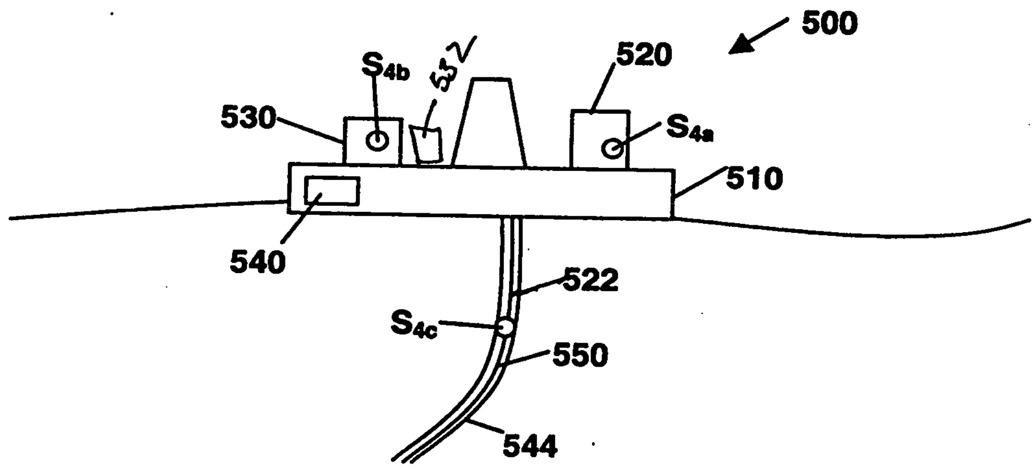

FIGURE 7A

DECLARATION AND POWER OF ATTORNEY FOR PATENT APPLICATION

As the below named inventors, we hereby declare that:

Our residence, post office address and citizenship are as stated below under our names.

We believe that we are the original, first and joint inventors of the subject matter which is claimed and for which a patent is sought on the invention entitled **"Subsea Chemical Injection Unit for Additive Injection and Monitoring System for Oilfield Operations,"** the specification of which was filed on **August 14, 2003**, receiving the Serial No. **10/641,350.**

We hereby state that we have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

We acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Sec. 1.56, including for continuation-in-part applications, material information which became available between the filing date of the prior application and the national or PCT international filing date of the continuation-in-part application.

We hereby claim foreign priority benefits under Title 35, United States Code, Sec. 119(a)-(d) or (f), or 365(b), of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below any foreign application for patent or inventor's certificate, or any PCT international application having a filing date before that of the application on which priority is claimed.

PRIOR FOREIGN APPLICATION(S)

NUMBER	COUNTRY	(DAY/MONTH/YEAR FILED)	PRIORITY CLAIMED	
			YES	NO

We hereby claim benefit under Title 35, USC, Sec. 120 of any United States application, or under Title 35, USC Sec. 119(e) of any provisional application, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in any prior United States application in the manner provided by the first paragraph of Title 35, USC, Sec. 112. I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56, which became available between the filing date of the prior application and the national or PCT international filing date of this application:

SERIAL NO.	FILING DATE	STATUS
60/403,445	August 14, 2002	

We hereby appoint, Stephen A. Littlefield (Reg. No. 27,923), Matt W. Carson (Reg. No. 33,662), J. Albert Riddle (Reg. No. 33,445), Darryl M. Springs (Reg. No. 24,799), Brian S. Welborn (Reg. No. 39,065), Timothy Donoughue (Reg. No. 46,668), Paul S. Madan (Reg. No. 33,011), Kaushik P. Sriram (Reg. No. 43,150), David L. Mossman (Reg. No. 29,570), G.

Michael Roebuck (Reg. No. 35,662), Todd A. Bynum (Reg. No. 39,488),), Gene L. Tyler (Reg. No. 35,395), William E. Schmidt (Reg. No. 47,064), Chandran D. Kumar (48,679), David A. Walker (Reg. No. 52,334), and Shawn Hunter (Reg. No. 36,168) as attorneys with full power of substitution and revocation to prosecute this application and transact all business in the Patent and Trademark Office connected therewith.

Please address all correspondence regarding this application to:

Chandran D. Kumar
Madan, Mossman & Sriram, P.C.
2603 Augusta Drive, Suite 700
Houston, Texas 77057

Direct all telephone calls to Chandran D. Kumar at (713) 266-1130x128.

We hereby declare that all statements made herein of our own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Sec. 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Inventor: Christopher Kempson Shaw

Residence: 104 NW Russell Drive
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Post Office Address: Same as Above

Citizen Of: United Kingdom

________________ ______________________

Date Christopher Kempson Shaw

Inventor: Cindy L. Crow

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________________ ______________________

Date Cindy L. Crow

Inventor: William Edward Aeschbacher, Jr.

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Sunder Ramachandran

Inventor: Mitch C. Means

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Date

Mitch C. Means

Inventor: Paulo S. Tubel

Residence: 118 E. Placid Hill
The Woodlands, Texas 77381

Post Office Address: Same as Above

Citizen Of: Brazil

Date

Paulo S. Tubel

ASSIGNMENT

IN CONSIDERATION OF ONE (1) DOLLAR AND OTHER GOOD AND VALUABLE CONSIDERATION, the receipt, sufficiency and adequacy of which are hereby acknowledged, the undersigned, do/does hereby:

SELL, ASSIGN AND TRANSFER to **BAKER HUGHES INCORPORATED**, having a place of business at **3900 ESSEX LANE, SUITE 1200, HOUSTON, TEXAS 77027**, the entire right, title and interest for the United States and all foreign countries in and to any and all inventions and improvements which are disclosed in the application for United States Letters Patent, which has been executed by the undersigned and is entitled **"SUBSEA CHEMICAL INJECTION UNIT FOR ADDITIVE INJECTION AND MONITORING SYSTEM FOR OILFIELD OPERATIONS,"** further identified as U.S. Application Serial No. **10/641,350**, filed **August 14, 2003**, such application and all divisional, continuing, substitute, renewal, reissue and all other applications for patent which have been or shall be filed in the United States and all foreign countries on any of such inventions or improvements; all original and reissued patents which have been or shall be issued in the United States and all foreign countries on such inventions or improvements; and specifically including the right to file foreign applications under the provisions of any convention or treaty and claim priority based on such application in the United States;

AUTHORIZE AND HEREBY REQUEST the issuing authorities to issue any and all United States and foreign patents granted on such inventions or improvements to **BAKER HUGHES INCORPORATED**;

WARRANT AND COVENANT that no assignment, grant, mortgage, license or other agreement affecting the rights and property herein conveyed has been or will be made to others by the undersigned, and that the full right to convey the same as herein expressed is possessed by the undersigned;

COVENANT, when requested and at the expense of the Assignee, to carry out in good faith the intent and purposes of this assignment, the undersigned will execute all divisional, continuing, substitute, renewal, reissue, and all other patent applications on any and all such improvements; execute all rightful oaths, declarations, assignments, powers of attorney and other papers; communicate to the Assignee all facts known to the undersigned relating to such improvements and the history thereof; and generally do everything possible which the Assignee shall consider desirable for vesting title to such improvements in the Assignee, and for securing, maintaining and enforcing proper patent protection for such improvements;

TO BE BINDING on the heirs, assigns, representatives and successors of the undersigned and extend to the successors, assigns and nominees of the Assignee.

IN WITNESS WHEREOF, the undersigned have hereunto subscribed their names on the date set opposite their signatures.

(Signature) ______________________________ Date ________________________
Name: Christopher Kempson Shaw

§
§

BEFORE ME, the undersigned authority, on this ____ day of _______, 2003 personally appeared the person, Christopher Kempson Shaw, whose name is subscribed to the foregoing instrument and acknowledged to me that he executed the same of his own free will for the purposes and consideration therein expressed.

____
Notary Public

(Signature) ______________________________ Date ________________________
Name: Cindy L. Crow

§
§

BEFORE ME, the undersigned authority, on this ____ day of _______, 2003 personally appeared the person, Cindy L. Crow, whose name is subscribed to the foregoing instrument and acknowledged to me that he executed the same of his own free will for the purposes and consideration therein expressed.

____
Notary Public

(Signature) ______________________________ Date ________________________
Name: William Edward Aeschbacher, Jr.

§
§

BEFORE ME, the undersigned authority, on this ____ day of _______, 2003 personally appeared the person, William Edward Aeschbacher, Jr., whose name is subscribed to the foregoing instrument and acknowledged to me that he executed the same of his own free will for the purposes and consideration therein expressed.

____
Notary Public

(Signature) ______________________________ Date ________________________
Name: Sunder Ramachandran

§
§

BEFORE ME, the undersigned authority, on this _____ day of ________, 2003 personally appeared the person, Sunder Ramachandran, whose name is subscribed to the foregoing instrument and acknowledged to me that he executed the same of his own free will for the purposes and consideration therein expressed.

____
Notary Public

(Signature) ______________________________ Date ________________________
Name: Mitch C. Means

§
§

BEFORE ME, the undersigned authority, on this _____ day of ________, 2003 personally appeared the person, Mitch C. Means, whose name is subscribed to the foregoing instrument and acknowledged to me that he executed the same of his own free will for the purposes and consideration therein expressed.

____
Notary Public

(Signature) ______________________________ Date ________________________
Name: Paulo S. Tubel

§
§

BEFORE ME, the undersigned authority, on this _____ day of ________, 2004 personally appeared the person, Paulo S. Tubel, whose name is subscribed to the foregoing instrument and acknowledged to me that he executed the same of his own free will for the purposes and consideration therein expressed.

____
Notary Public

Tubel Technologies, Inc.

TUBEL TECHNOLOGIES INCORPORATED

Contact TTI

Tubel Technologies is located 20 miles North of Houston's Bush Intercontinental airport in The Woodlands, Texas. Tubel Tech has its main offices in the Houston Advanced Research Center where its research, engineering and manufacturing is performed.

Tubel Technologies Inc.
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The Woodlands, TX 77381

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